Vol. 7 APRIL, 1924 No. 4

Journal

of the

American Ceramic Society

Abstracts Bulletin

A Monthly *Journal* Devoted to the Arts and Sciences Related to the Silicate Industries

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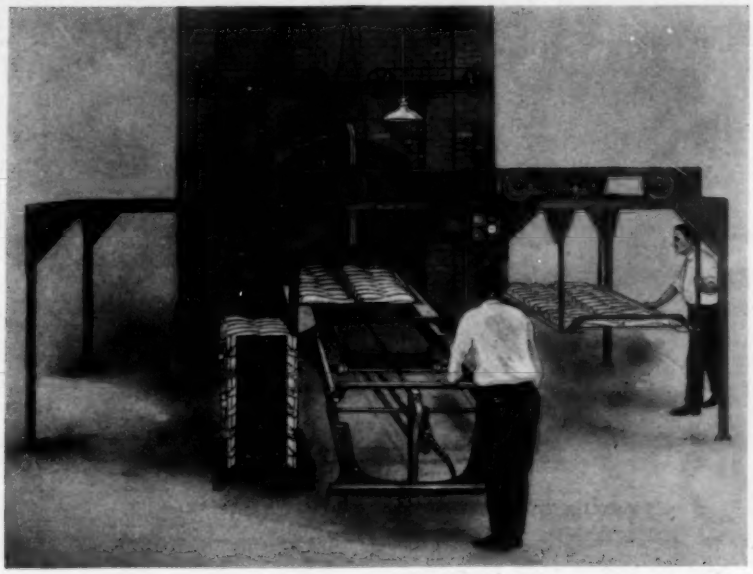

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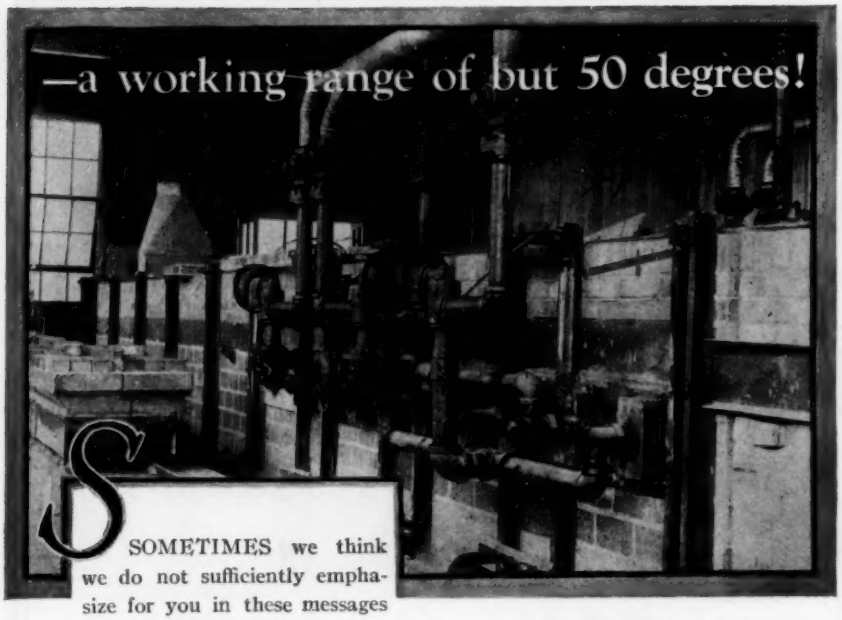

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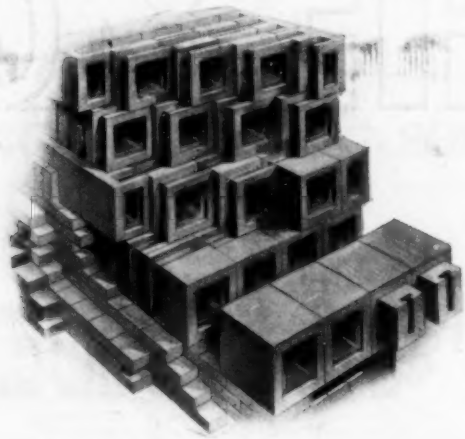

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Publication Office: 211 Church St., Easton, Pa.
Editorial and Advertising Offices: Lord Hall, O. S. U., Columbus, Ohio.
Committee on Publications: F. K. Pence, Chairman; A. W. Kimes, F. H. Rhead, W. E. Dornbach, Rosa C. Purdy.
Editor: Ross C. Purdy; **Assistant Editor:** Emily C. Van Schoick; **Associate Editors:** L. E. Barringer, E. W. Tillotson, Roy Horning, R. R. Danielson, A. F. Greaves-Walker, F. H. Rhead, H. Ries, R. L. Clare.

Entered as second-class matter July 15, 1918, at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 16, 1918.

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Twelve dollars a year Single numbers, one dollar
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Vol. 7 **April, 1924** **No. 4**

ORIGINAL PAPERS

THE OXIDATION OF CERAMIC WARES DURING FIRING.—II. THE DECOMPOSITION OF VARIOUS COMPOUNDS OF IRON WITH SULPHUR UNDER SIMULATED KILN CONDITIONS[1]

By Frederick G. Jackson[2]

ABSTRACT

The progress of sulphur evolution is traced from a series of clay bars containing known amounts of various iron-sulphur compounds, both with and without the addition of carbon, when heated in imitation of a kiln schedule in atmospheres varying from pure oxygen to those commonly encountered in kiln practice, including neutral and reducing atmospheres. The varying degree of incompleteness of sulphur evolution is noted. The residual sulphur is found to be practically insoluble in water or aqua regia, but is rendered soluble by hydrofluoric acid. As a plausible explanation there is advanced the theory of the formation of "ferrous sulpho-silicate."

Introduction

In a previous paper[3] of this series the oxidation of carbon in a particular clay was discussed, and some rather striking facts were presented in connection with the evolution of sulphur by the clay. A series of conclusions of a tentative nature was added, but nothing very definite could be deduced from these results, since there are so many unknown factors enter-

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[2] Associate Chemist, Ceramic Station, Columbus, Ohio.

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ing into the problem, so the object of the work described in this present paper was to study this matter more fully.

In burning a natural clay to make a ceramic ware the following factors may influence the nature and rate of evolution of sulphur from the ware:

1. Nature of the sulphur compound.
2. Grain size of the sulphur compound.
3. Amount of sulphur present.
4. Presence or absence of certain substances in the clay.
5. Structure of the clay.
6. Rate of heating the kiln.
7. Nature of the kiln atmosphere.
8. Rate of ventilation of the kiln.

In the experimental part of this investigation, the first five of these factors were controlled by using a very pure kaolin, to which was added known quantities of various impurities in imitation of natural clays. In general, the conditions employed were as close to kiln practice as possible. The rate of heating was on a progressive schedule in imitation of a kiln, and the atmospheres used at various times simulated the limiting and normal conditions in kiln practice.

Clay Used in Experiments

The clay used was a plastic kaolin, which gave the following analysis:

Constituent	Per cent	Constituent	Per cent
SiO_2	45.11	MgO	0.12
Al_2O_3	38.59	K_2O	0.00
Fe_2O_3	0.60	Na_2O	0.00
TiO_2	1.36	Sulphur	0.02
P_2O_5	0.03	Ignition loss	13.81
CaO	0.02		
			99.66

In order to study the reaction of each type of sulphur compound with iron, this clay was mixed in separate lots with ferrous sulphide, pyrite, ferric sulphate, ferrous sulphate, etc. The effect of grain size of the pyrite was also studied by using separate lots of 10- to 48-mesh and through 200-mesh. The effect of the presence of carbon on the sulphur in clay was also studied by making some test pieces containing ground coal or lamp black. For each case, 60 grams of clay were weighed and crushed. One and one-half grams of the iron-sulphur compound were then added, this being an amount of impurity frequently existing in natural clay, and, in some cases, 1.5 grams of carbon. These were ground carefully together and well mixed, then tempered with distilled water, thoroughly pugged, and rolled out into a bar. These bars were suitably numbered and air dried, then dried at 110°C for a week and kept in a desiccator.

Heating Schedule

In adopting a kiln schedule to a tube furnace of laboratory size, four factors had to be considered—namely, (1) the ratio of surface exposed to volume of clay; (2) the depth of penetration necessary; (3) the ratio of volume of gas to weight of clay; and (4) the rate of heating. The ratio of surface exposed to volume of clay is fifteen times as great in the tube furnace as in the face brick kiln, the schedule of which was simulated. The necessary penetration is only one-tenth as great. It therefore seemed proper, on passing to a laboratory scale, to divide the time of heating by ten, and the volume of gas per unit weight of clay per hour by two. This gave conditions that could be handled in the laboratory.

Since the clay was bone dry, it was possible in the laboratory to attain a temperature of 425°C in an hour. Therefore, by making a long day of it, it was possible to study the crucial part of the burn (425° to 775°C) in a single day's run.

A heating schedule was adopted from a commercial kiln and strictly adhered to throughout most of the experiments presented in this paper. This ran as follows:

Period, hours	Temp., °C	Period, hours	Temp., °C
1	425	6	615
2	445	7	665
3	480	8	720
4	510	9	775
5	560		

This schedule was modified in some cases so that 720° was attained in $7^1/_2$ hours and 775° in 8 hours. This did not affect the results, since reactions were practically complete by that time.

Temperature Measurement

To know the temperature under such conditions, a thermocouple must be in actual contact with the clay, rather than outside the tube, as in previous work. A noble-metal couple (platinum-platinum rhodium) will not register these temperatures so accurately, so a base-metal couple was inserted through the stopper at the intake end of the combustion tube, touching the end of the clay bar. A fused quartz combustion tube, drawn down to small bore at the outlet end, was used.

Absorption of Sulphur

Preliminary experiments showed that, with the large amount of water of combination in this clay, the previously used absorption apparatus would not do at all. Too much of the sulphur came off as sulphuric acid mist. Since sulphur was the object of the investigation, a method was sought

of collecting this mist in a form that could easily be analyzed. The method adopted was to pass the gas from the combustion tube through damp asbestos. A short glass tube was connected to the outlet end of the combustion tube, and was bent at right angles downward. Onto the end of this a one-hole rubber stopper was slipped. This stopper sealed the top of a porcelain perforated (Gooch) crucible. In the bottom of the crucible was a thin asbestos mat. This condensed the sulphuric acid mist entirely, but was not attacked by it. The crucible was set in the customary way in a Gooch funnel, the end of which was bent at right angles. To this was attached a potash bulb, which was connected to gentle suction. This suction was necessary in order to get the gas through the asbestos mat without developing an excess pressure inside the combustion tube. Such a pressure would be unlike kiln conditions, and might change the course of reactions. A manometer was set in the intake line of the gas supply, and pressure was kept close to atmospheric by the regulation of valves. The apparatus is shown in Fig. 1.

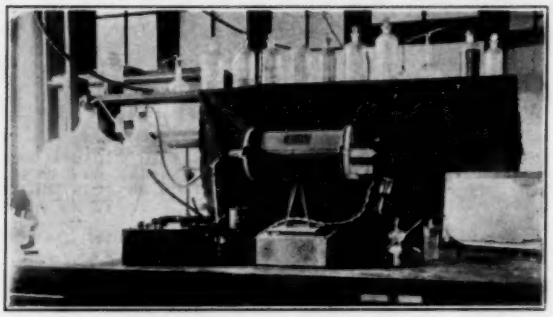

FIG. 1.—General view of apparatus.

At the end of each hour the incoming gas was stopped for a minute, the crucible and potash bulb were removed, and fresh ones were substituted and the gas flow continued. The used crucible was then rinsed by blowing three lots of distilled water through it. The washings were caught in a 100-cc. graduate flask. The Gooch funnel and the potash bulb were in turn rinsed into this flask, which was then filled to the mark with water, divided in two equal parts, and analyzed as before for SO_3 and SO_2.

Combustion Atmosphere

The atmosphere of a kiln may vary greatly under different conditions, and in order to study all possible variations, three different atmospheres were produced, a run being made with each on each class of impure or prepared clay. Pure oxygen was used, as being the extreme of oxidizing conditions. Then a mixture of 10% CO_2 and 90% air was used. This is similar to water-smoking conditions in a kiln when 200% excess air is passing, since there is about twice as much oxygen as CO_2. The third atmosphere was 10% CO_2, 50% air, and 40% nitrogen. This gives

equal parts of CO_2 and oxygen, and corresponds to the best conditions in the middle of a burn, when there is 100% excess air in the flue gas. Oxidized iron-sulphur compounds were also studied in an atmosphere of pure nitrogen, and in an atmosphere of 90% nitrogen, and 10% hydrogen. It will be shown that the nature of the atmosphere has a marked effect on the burning. These mixed atmospheres were prepared in graduated 5-gallon bottles by adding the desired quantity of gas from a tank to a bottle full of water, while the bottle was being drained by syphon. Air was similarly drawn from the room. The mixed gas was forced out by a slow stream of water that was forced in. Since the gas did not bubble through the water, and the water was not agitated and was in contact with gas for only a few hours, the amount of CO_2 dissolved by the water was negligible.

Procedure

A typical day's run of the process was as follows: The cooled bar from the previous day was removed from the combustion tube and weighed. The new bar, dried at 110°C, was then weighed and put into the tube, the current turned on, and the rheostat set so that the temperature would reach 425° in an hour. A fresh absorption train was attached, and the gas flow started. The gas flow and the suction were so adjusted that the pressure remained atmospheric in the tube, and the speed of gas passing was correct. The filtration, ignition, and weighing of the 18 barium sulphate precipitates of the previous day were then begun and completed during spare moments of the day. At the time that 425° was reached the rheostat was cut back. Adjustment was made in accord with frequent temperature readings thereafter, so that the heating schedule was maintained. At the end of each hour the absorption train was changed. The spent one was then rinsed out, refilled, and placed in readiness.

The flasks containing rinsings were numbered and set aside. When sufficient had accumulated, they were each filled to the mark with distilled water and each emptied into a beaker so as to mix thoroughly. From each beaker 50 cc. were measured out in a graduate and put into a second beaker, all beakers being properly marked. The graduate and graduated flask were then rinsed into the beakers. Half of the beakers were then each neutralized with an excess of HCl and boiled for five minutes. In some cases the smell of SO_2 evolved was quite noticeable. When this was gone, barium chloride solution was slowly added to the boiling liquids until precipitation was complete. The beakers were then removed and allowed to stand over night, so that the $BaSO_4$ was in proper condition to filter. The remaining beakers were then neutralized with concentrated nitric acid in excess, and bromine water was added. These two powerful oxidizing agents converted all SO_2 to SO_3. In a few cases,

as will be described later, H_2S was formed to some extent. The HNO_3 first precipitated this as sulphur. Bromine water on standing would dissolve and oxidize this to H_2SO_4. This sulphur precipitate would also be formed from H_2S in the beaker neutralized with HCl. It was allowed to remain, since it burnt off completely on igniting the precipitate.

After the bromine color had persisted for five minutes, $Ba(NO_3)_2$ solution was added. The liquid was then boiled until free of bromine color, and until the addition of more $Ba(NO_3)_2$ solution did not increase the precipitate. It was then also set aside over night, after dilution to a volume of about 200 cubic centimeters.

On account of difficulty in starting the precipitation of $BaSO_4$ in the presence of HNO_3, this procedure was later modified. Bromine water in excess was added to the alkaline solution, HCl then added, and precipitation was effected, after boiling, with $BaCl_2$.

In the meantime, the temperature was being watched and maintained, pressure regulated, absorption trains washed out and prepared and changed at the proper times, and new gas mixtures prepared as required.

Determination of Evolved Hydrogen Sulphide

When conditions were temporarily reducing in some of the early experiments, the evolution of some H_2S was noticed. No effort was made at first to determine this separately from SO_2, but the two were oxidized together and determined as $BaSO_4$.

The quantitative determination of H_2S appeared of importance in some cases. Accordingly, the absorption apparatus was modified on occasion so that the gas from the combustion tube first bubbled through a solution of cadmium chloride, then passed on through the customary Gooch crucible with asbestos mat and potash bulb. At the end of each hour this train was replaced with a fresh one. The cadmium chloride solution was then examined for sulphide, and if any of this yellow precipitate was seen, it was filtered out and washed. The filter paper and precipitate were then put into a beaker of distilled water, pulped with a glass rod, a little starch paste added, then an excess of HCl added, and the liberated H_2S at once titrated with a standardized iodine solution. This iodine was stored in a bottle painted black, from which it was forced by air pressure through all glass connections to a burette. But in spite of these precautions to keep iodine away from light and rubber, the solution deteriorated slowly, and required daily comparison with a standard sodium thiosulphate solution. With this comparison as a basis, the sulphur content of each CdS precipitate was calculated; SO_3 and SO_2 were then determined as usual in the filtrate of the CdS precipitate, to which the caustic soda and washings of the Gooch crucible had been added.

Possible Sources of Error

There are many possible sources of error in the apparatus, which were guarded against as follows:

1. Sulphur compounds might be in the gases forced into the combustion tube: The oxygen and nitrogen were tested and found to be sulphur free. The CO_2 was passed through limestone chips, and the room was aired before drawing in air in case the atmosphere seemed the least tainted.

2. Sulphur might be generated from the rubber stopper in the intake end of the combustion tube; however, it survived 25 runs without evidence of any charring. Also some of the runs made showed no sulphur evolved at the highest temperatures, when such action would be most likely to occur.

3. Sulphur-bearing gases may be lost in changing absorption trains. The inflow of gas was always first stopped. Then the crucible was loosened from the rubber stopper, and held close to it for a few moments with suction running. This drew in any gas that might still come from the tube and all that was inside the crucible.

4. Sulphuric acid mist may pass through the asbestos pad and fail to be absorbed, due to a hole in the mat: This actually happened on three occasions. It could be detected at once because white smoke gathered in the potash bulb as soon as the gas flow started. In these cases the gas flow was stopped again at once, the crucible detached, and a little more asbestos pulp poured into it. The suction formed this into a perfect mat at once. The small amount of mist that had passed the mat was naturally diluted with mist-free gas before reaching the soda solution, and was practically all absorbed so that the loss was negligible.

5. Sulphur dioxide may not be completely absorbed by the soda solution; tests, with a second bulb added, proved that absorption was complete. The gas in all cases bubbled through four successive reservoirs of solution. There was a large excess of soda present, so that although in some cases nearly 0.5 gram of SO_2 was absorbed in a single hour, as well as the CO_2 that was passing, this excess was only slightly impaired.

Presentation of Results

By following the method described above as applied to each variety of impure or prepared clay with each atmosphere, considerable data were obtained. Simplification was necessary before presentation. Accordingly, the weight of SO_3 or SO_2 found to have been evolved in each hour was recalculated to the corresponding weight of sulphur. Then was calculated what percentage this was of the total sulphur added to the clay. The percentage per hour of the total sulphur evolved both as SO_3 and as SO_2 is shown in tabular form in each case. This is followed by curves, which

show the cumulative evolution of sulphur. In each case the lower curve shows the SO_3, and the area subtended by the curve shows the amount so far evolved. The upper curve shows SO_2 plus SO_3. The area between curves shows the amount of SO_2 evolved. Where H_2S was measured, this is similarly added above in a third curve. In all cases that appeared at all abnormal, the results were checked by repeating the experiment.

Interpretation of Results

Ferrous Sulphide in Clay.—Although FeS does not occur naturally in raw clay, it was studied in this series of experiments because it is in al probability formed as an intermediate product in the oxidation of pyrite

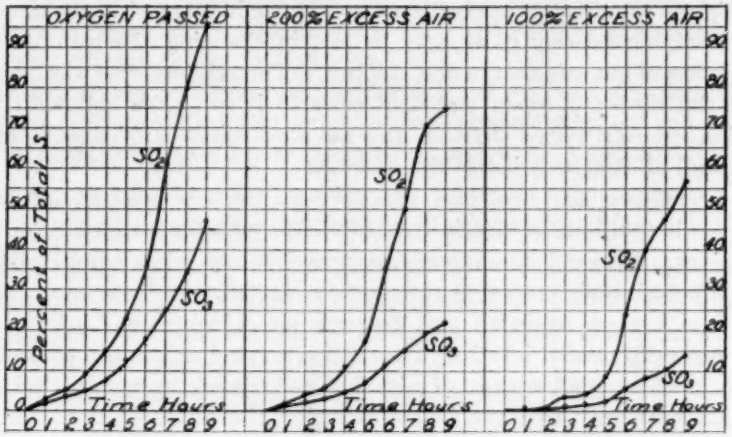

FIG. 2.—Ferrous sulphide.

Its behavior is the simplest, and will, therefore, be considered first. When treated with pure oxygen, it begins to oxidize at low temperature by the reaction

$$4FeS + 9O_2 = 2Fe_2O_3{}^1 + 4SO_3$$

Since this reaction does not generate appreciable heat, it proceeds slowly. As the action proceeds at increasing temperatures there is an increasing tendency for the SO_3 already formed to give up one of its atoms of oxygen to burn more FeS in this manner:

$$2FeS + 7SO_3{}^1 = Fe_2O_3{}^1 + 9SO_2{}^1$$

There is also the possibility of direct formation of SO_2 as follows:

$$4FeS + 7O_2 = 2Fe_2O_3{}^1 + 4SO_2$$

[1] There may well be an intermediate stage in which at first a lower oxide of iron such as Fe_3O_4 is formed. This will later oxidize to Fe_2O_3. This step is omitted for simplicity in these reactions.

The resultant of these forces, in the case of oxygen, is an evolution of almost equal parts of SO_3 and SO_2, very close to 47% of the total sulphur being evolved in each way. There seems to be little, if any, other action. Appearances are all to the effect that, if heating had been continued at the same rate for another hour, all of the sulphur would have been evolved.

When we cut down the oxygen content of the gas passing to about 18%, the oxidation of sulphur is retarded. There is also, naturally, the tendency for the reactions using less oxygen to predominate. Thus we have 21% of the sulphur going off as SO_3 and 53% as SO_2 in the course of this run. The general trend of the burning remains unchanged. There is only a slowing up of the actions.

On still further cutting down the oxygen content, this slowing up is still more marked. Only 13% of the sulphur comes off as SO_3 and 43% as SO_2. The general tendency of the curves (Fig. 2) is not, however, altered in kind, but only in degree. It must be remembered that, even in this case, there is a little more than enough oxygen passing during each hour to convert all of the sulphur added to the clay into SO_3.

TABLE I

RESULTS OF TREATMENT OF CLAY WITH FERROUS SULPHIDE

Time, hours	Temp., °C	Oxygen		200 per cent excess air		100 per cent excess air	
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2
1	425	2.19	0.29	1.32	0	0	0
2	445	0.99	1.18	0.68	1.21	0	0
3	480	1.31	2.48	0.87	1.32	0.49	2.20
4	510	2.79	2.07	1.50	3.69	0.30	0.27
5	560	4.92	4.30	2.39	3.98	0.62	3.89
6	615	5.65	7.45	4.24	13.52	2.38	11.81
7	665	6.65	19.23	3.88	10.43	2.52	13.58
8	720	9.20	9.35	4.04	16.85	2.13	5.07
9	775	13.10	2.35	2.22	3.75	3.67	6.31
	TOTALS	46.80	48.70	21.41	54.75	12.11	43.13
Total per cent sulphur evolved		95.50		76.16		55.24	

Fine Pyrite in Clay

When fine FeS_2 is burned in clay in an atmosphere of oxygen, what amounts almost to an explosion takes place at just about 425°. The reaction $FeS_2 + O_2 = FeS + SO_2$ generates a considerable amount of heat. Once it has started, it raises the temperature of the surrounding clay, and runs with rapidity to completion. There are a number of additional reactions that may take place, due to this sudden heating, such as—

$$4FeS + 9O_2 = 2Fe_2O_3 + 4SO_2$$
$$4FeS + 7O_2 = 2Fe_2O_3 + 4SO_2$$
$$4FeS + 6O_2 = 4FeSO_4, \text{ or some similar compound.}$$

The very fact that more than half of the total sulphur present is evolved during the first two hours proves that some second reaction takes place by which some of the second atoms of sulphur are liberated. Beyond this point the gas evolution proceeds as if there were a mixture of FeS and $Fe_2(SO_4)_3$ present. This may well be the case. If molecules of FeS have started to oxidize without losing their sulphur, they would probably behave similarly to $Fe_2(SO_4)_3$ molecules on further heating.

When air containing 10% CO_2 was passed, the procedure was changed but little. The first explosion was slightly damped, only 58% of the sulphur coming off in the first two hours, as compared with 62% in the previous case. A little less of this was SO_3 than in the first case. This would be expected with less oxygen present. In this case either the heating was a trifle faster or the change of absorption trains was not made at exactly the same moment, so that the bulk of SO_2 was caught in the first hour rather than in the second. This difference should be set down to

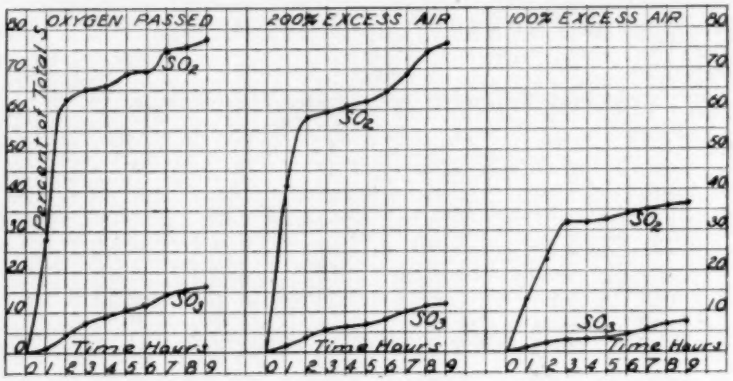

FIG. 3.—Fine pyrite.

experimental inaccuracy. It is evident from laboratory observation that almost all of this gas is generated and absorbed between 50 and 70 minutes after the heating is started. The curve (Fig. 3) of gas evolution from then on closely resembles that of ferrous sulphide under similar conditions. More SO_2 and less SO_3 is generated than in the last case when oxygen was more abundant. Also, actually more sulphur is evolved. The difference of 4% after 2 hours becomes 1.5% after 9 hours. This would be expected if less of the ferrous sulphide were oxidized by the "explosion" to some iron-sulphur-oxygen compound. This was probably the case, since the explosion was less violent.

When the amount of oxygen in the gas was still further reduced, the first explosion was greatly retarded. It took place during parts of the first three hours, and not even all of the first atoms of sulphur were evolved

then. During the fourth hour the evolution of sulphur was very slight. It was also noticed on neutralizing the caustic soda which was used to absorb the SO_2 that no CO_2 had come through the combustion tube. The sulphur in the clay must have been very eager for oxygen to have decomposed CO_2 to CO. It is possible that a hyposulphite of iron was forming, with two atoms of sulphur to each atom of iron, similar to FeS_2O_3, although no such compound has ever been isolated. A more reasonable explanation, however, lies in the fact that the original clay, the purest obtainable, contained 0.60% of iron. This iron was probably originally oxide and absorbed some of the SO_2 which had been liberated from the FeS_2. Due to the comparatively limited oxygen supply, it is probable that the iron-sulphur-oxygen compound formed is not ferric sulphate to any great extent, but some ferrous compound. However, the sulphur evolution during the rest of the run was only from 31 to 36%, and almost all of this was SO_3. There seems to be some reaction going on here which is not yet explained, and this will be studied later.

TABLE II

RESULTS OF TREATMENT OF CLAY WITH FINE PYRITE

Time, hours	Temp., °C	Oxygen		200 per cent excess air		100 per cent excess air	
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2
1	425	0.86	26.90	1.21	39.80	0.62	11.78
2	445	3.72	30.80	2.12	14.30	1.37	8.70
3	480	2.57	0	1.87	0.20	0.53	8.42
4	510	0.91	0.15	0.74	0.10	0.12	0.31
5	560	2.50	0.30	0.84	0.10	0.37	0.22
6	615	0.65	0.25	1.14	0.50	0.95	0
7	665	3.25	2.10	1.51	2.30	1.31	0
8	720	0.79	0	1.64	4.20	1.08	0
9	775	1.29	0.40	0.81	1.50	0.60	0
TOTALS		16.54	60.90	11.88	63.00	7.01	29.43
Total per cent sulphur evolved		77.44		74.88		36.44	

Fine Pyrite with Lamp black

When pyrite and lamp black are mixed in clay and burned in oxygen we have all of the ingredients of old-fashioned gunpowder—namely, sulphur, charcoal and oxygen. It is little wonder, therefore, that when this reaches its ignition temperature it burns with a rush. Over 64% of the sulphur came off in the first hour, nearly all as SO_2. The last portions of this burning were completed in the next two hours, making a total of 84% of the sulphur evolved. After that only traces of sulphur came off, practically all as SO_3.

With the normal kiln atmosphere, a more satisfactory combustion takes place. The conditions of pyrite and lamp black burned in 90% air and

10% CO_2 are very similar to kiln practice on a normal fire clay. Here the explosion takes place more slowly. There is not enough oxygen to burn all of the lamp black rapidly.

It was earlier stated that there was a little more than enough oxygen passing when 100% excess air was used to burn all of the sulphur in 1.5 grams of FeS in one hour. While this is true, it must be realized that to burn 1.5 grams of carbon requires much more oxygen. It requires all of the oxygen passed for three hours to convert this carbon to CO.

During the fourth hour a little of the sulphur came off as H_2S. This could happen by any of several reactions such as—

$$SO_2 + 3CO + H_2O = H_2S + 3CO_2$$
$$FeS + H_2O = H_2S + FeO$$

Conditions appeared to be so well adjusted in this burn that the greatest yield of sulphur gas was obtained of any of the pyrite burns.

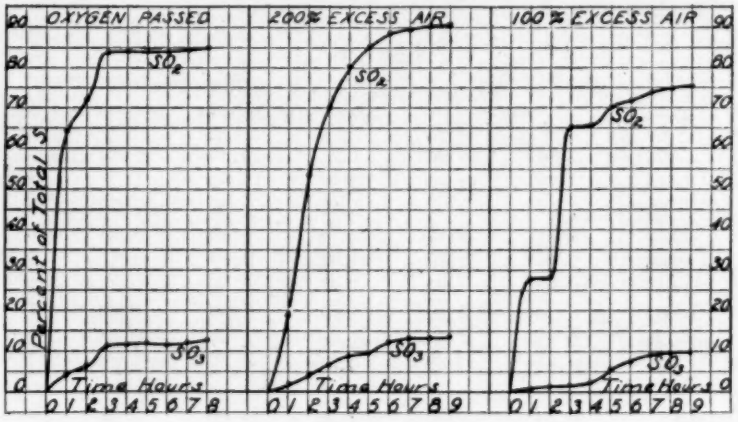

FIG. 4.—Fine pyrite and lamp black.

With the minimum oxygen supply, an interesting analysis of the explosion is shown. Reverting to the analogy of gunpowder, it is well known that sulphur was not desired in gunpowder. It formed fumes which corroded the gun barrel, but it ignited at a lower temperature than carbon, and so was put in to make the explosion start more readily. In this experiment we see 27% of the sulphur burnt off in the first hour, and none in the second hour; also in the second hour no CO_2 was evolved. Therefore, the sulphur must have "caught fire" first, and heated the lamp black up to its ignition point. The CO then formed smothered the burning of the sulphur completely for the space of the second hour, then sulphur again burned in the third hour, until over 65% was gasified, and, therefore, the most readily combustible part of it was all gone. Then

followed a period of oxidation through the fourth hour, with little evolution of sulphur and complete reduction of CO_2. This was followed by the now familiar phenomenon of only a few per cent of the remaining sulphur being evolved through the rest of the run, and mostly as SO_3. (See Fig. 4.)

TABLE III

RESULTS OF TREATMENT OF CLAY WITH FINE PYRITE AND LAMP BLACK

Time, hours	Temp., °C	Oxygen		200 per cent excess air		100 per cent excess air	
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2
1	425	4.28	59.70	1.65	16.73	0.47	26.70
2	445	1.71	6.10	1.97	32.52	0.11	0[2]
3	480	5.22	6.30	3.17	13.44	0.75	36.90
4	510	0.10	0	1.56	8.70[1]	0.29	0.60[2]
5	560	0.18	0	0.63	3.97	3.61	1.00
6	615	0.12	0	2.97	0.85	1.48	0
7	665	0.37	0	0.55	0.41	1.74	0
8	720	0.16	0.15	0.29	0.45	0.39	0.70
9	775	0.27	0	0.48	0	0.33	0.30
TOTALS		12.41	72.25	13.27	77.07	9.17	66.20
Total per cent sulphur evolved		84.66		90.34		75.37	

[1] H_2S noted.
[2] No CO_2 caught.

Coarse Pyrite

When coarse FeS_2 was burned in oxygen it did so more slowly than the fine pyrite. The grains were larger and fewer, and therefore farther apart;

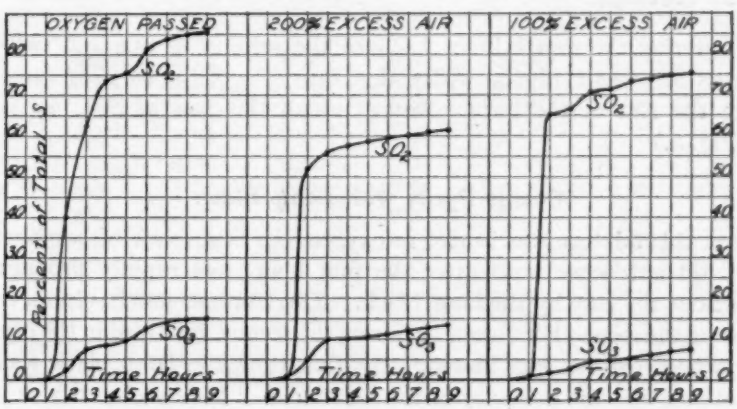

FIG. 5.—Coarse pyrite.

and so the original spark of combustion may not have been transmitted as rapidly. For that reason the furnace would be hotter, when the burning was taking place and the gas evolution was, therefore, greater.

When heated with the normal kiln atmosphere of 200% excess air, the burning of sulphur had just begun at the end of the first hour. A little over 50% of the sulphur came off in the first two hours, almost all as SO_2. During the third hour the evolution of SO_2 came to an end, and the SO_3 continued to be given off slowly until the end of the run.

When the minimum oxygen supply was furnished to coarse FeS_2, a most surprising evolution of 65% of the sulphur as SO_2 took place during the second hour. Followed the customary periods of oxidation, when during the third and fifth hours almost no sulphur and no CO_2 came off, between

TABLE IV

RESULTS OF TREATMENT OF CLAY WITH COARSE PYRITE

Time, hours	Temp., °C	Oxygen		200 per cent excess air		100 per cent excess air	
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2
1	425	0.32	0	0.69	0.75	0.44	0.17[1]
2	445	1.81	38.50	4.17	47.00	1.30	63.08
3	480	5.16	16.80	4.55	4.10	0.21	0[1]
4	510	1.48	9.50	1.03	0.10	1.63	3.35
5	560	0.96	1.20	0.49	0.20	0.11	0[1]
6	615	2.57	3.40	0.57	0.10	1.24	0.65
7	665	1.13	1.10	0.86	0.40	0.45	0
8	720	0.67	0.25	0.35	0	0.80	0
9	775	0.63	0.50	0.62	0	0.73	0.30
TOTALS		14.73	71.25	13.33	52.65	6.91	67.55
Total per cent sulphur evolved		85.98		65.98		74.46	

[1] No CO_2 caught.

which, during the fourth hour, 1.6% of the sulphur as SO_3 and twice as much as SO_2 was evolved. After this, only 3% of the sulphur came off during the rest of the burn. Almost all of this was as SO_3, as usual. (See Fig. 5.)

Coarse Pyrite with Lamp Black

When this mixture was heated in oxygen, the first spark of combustion which did not occur until after the first hour, was rapidly propagated throughout the clay by the lamp black. Therefore, as much sulphur came off during the second hour alone as during the second and third in the experiment where carbon was absent. By this time the lamp black was all burned out, and the behavior of the remainder of the two burns was very similar. The final yields in the two cases were almost identical.

With the normal kiln atmosphere of 200% excess air the yield was 6% better than when lamp black was absent under similar circumstances. The SO_3 was less, due to the reducing conditions. After the fifth hour no SO_2 and very little SO_3 was given off.

With the atmosphere lowest in oxygen content, the main sulphur evolution was spread out through five hours. However, the yield was higher than in the former case, and SO_2 continued to be formed throughout the burning time. During the second, third, and fourth hours, H_2S was

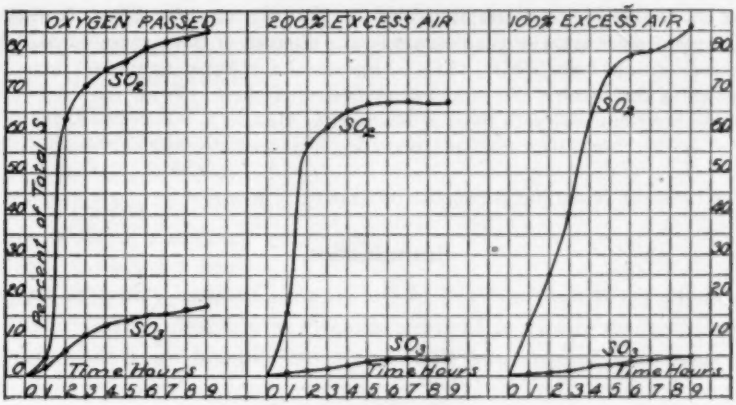

FIG. 6.—Coarse pyrite and lamp black.

formed to some extent. Apparently, conditions were such that only disulphide and sulphide can exist as solids. These compounds then decompose to H_2S and SO_2. (See Fig. 6.)

TABLE V

RESULTS OF TREATMENT OF CLAY WITH COARSE PYRITE AND LAMP BLACK

Time, hours	Temp., °C	Oxygen		200 per cent excess air		100 per cent excess air	
		SO_3	SO_2	SO_3	SO_2	SO_3	SO_2
1	425	2.40	2.25	0.76	16.50	0.19	11.19
2	445	3.95	54.90	0.43	39.80	0.39	11.76[1]
3	480	3.91	4.30	0.23	3.20	0.97	15.45[1]
4	510	1.98	2.65	1.48	2.90	0.55	20.60
5	560	0.85	0.40	0.49	1.10	0.71	10.80
6	615	1.57	2.30	0.23	0	0.48	3.90
7	665	0.69	0.35	0.28	0	0.61	1.00
8	720	1.16	0.40	0.09	0	0.33	1.70
9	775	0.58	0	0	0	0.64	3.40
TOTALS		17.09	67.55	3.99	63.50	4.87	79.50
Total per cent sulphur evolved		84.64		67.49		84.37	

[1] H_2S noted.

(The second part of this paper will appear in the May Journal)

THE SYSTEM: $Al_2O_3.SiO_2$

By N. L. Bowen and J. W. Greig[1]

ABSTRACT

This paper deals with a study of the equilibrium relations of mixtures of pure alumina and silica at high temperatures. The results are expressed concisely in the form of an equilibrium diagram and their bearing on ceramic problems is discussed.

The principal feature of the diagram is the absence of the compound $Al_2O_3.SiO_2$, the only compound being $3Al_2O_3.2SiO_2$. Crystals of this latter compound occur in all alumina-silica refractories. The optical properties of these crystals have been determined and are compared with those of sillimanite, $Al_2O_3.SiO_2$, which has hitherto been regarded as the crystalline compound occurring in refractories and clay bodies in general.

The behavior of natural sillimanite on heating is discussed.

Introduction

Clay, the great raw material of the ceramic industry, may be regarded as consisting essentially of hydrous silicates of alumina. Many clays are, to be sure, very impure and their properties depend upon the impurities to a considerable extent, but the better grades contain little else than silica, alumina, and water, so that a knowledge of the behavior of alumina-silica mixtures at high temperatures is fundamental to an understanding of the behavior of such clays at these temperatures. Especially is this true at the present time when so much experimentation is going forward in the production of highly refractory wares involving the use of special clays and of mixtures imitating in composition the natural mineral sillimanite, $Al_2O_3.SiO_2$, which composition is believed to have special virtues.

Fig. 1.—Fragment of tank block showing thick crust of corundum (dark) formed by the action of glass on the clay body.

A knowledge of the behavior of alumina-silica mixtures at elevated temperatures is of no less importance to the geologist, for these same clay materials are frequently heated under natural conditions and the geologist must strive to interpret the changes which they have undergone. Indeed it was largely from geologic considerations that the impetus came for a reinvestigation of the alumina-silica system. Shales and related rocks when heated as a result of immersion in igneous magmas often have free alumina, as corundum, developed in them by reaction with the magma. This may be true even when the total compositions indicate an ample supply of silica to form sillimanite,[2] $Al_2O_3.SiO_2$. Development of

[1] Presented at the Atlantic City Meeting, Feb., 1924. (Refractories Division.)

[2] H. H. Thomas, "The Best Described Examples Are Those from the Island of Mull," *Quar. Jour. Geol. Soc.*, **78**, 229 (1922).

corundum under quite similar conditions may occur where artificial silicate melts (glasses) react with refractory clay bodies at their mutual contact surfaces. An excellent example of this is shown in the photograph, Fig. 1. Now the most probable interpretation of this setting-free of corundum is that sillimanite itself melts incongruently, breaking up into corundum and liquid. The system $Al_2O_3.SiO_2$ had formerly been investigated at this Laboratory, the problem being among the very earliest studied here. The results then obtained were believed to show a maximum or congruent melting point (1816°) at the composition of sillimanite with a eutectic between sillimanite and corundum (1810°). (See Fig. 2.)[1] The difference between these temperatures is less than the limit of error of measurement at such temperatures and on such materials, so that the existence of a eutectic cannot be regarded as definitely proved. The possibility of incongruent melting is therefore not altogether precluded. Further investigation of this point was thus indicated and was accordingly undertaken.

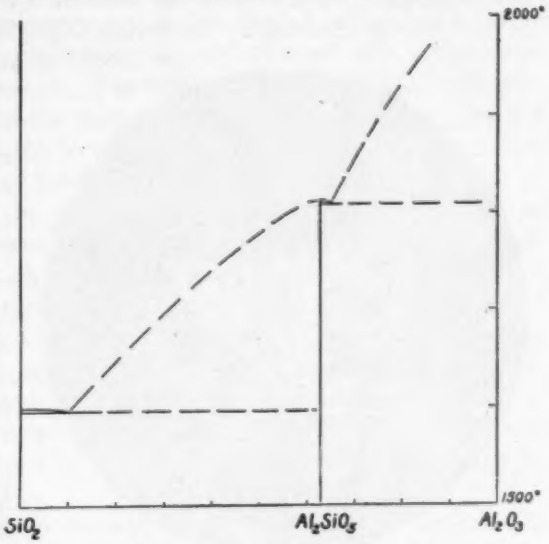

FIG. 2.—Equilibrium diagram of the system: $Al_2O_3.SiO_2$ after Shepherd, Rankin and Wright.

Preliminary trials with both natural sillimanite and with a mixture of Al_2O_3 and SiO_2 in the 1:1 ratio showed that, when they were heated to a very high temperature and slowly cooled, good corundum crystals were formed (see Fig. 3) showing that there is indeed a temperature region in which corundum exists in contact with liquid in a mixture of the composition of sillimanite. At the same time it was found that under no conditions that we were able to realize could the 1:1 mixture be induced to form a homogeneous mass consisting only of crystals corresponding with natural sillimanite. Even when not heated to the very high temperature where corundum forms, the mass always consists of two phases, the one, crystals having properties closely related to those of natural sillimanite; the other, interstitial glass. Precisely the same observation was made

[1] Shepherd, Rankin and Wright, *Am. J. Sci.*, **28**, 302(1909).

in the earlier work, Wright commenting as follows: "In every preparation of sillimanite examined there was present between the sillimanite fibers an isotropic substance of much lower refractive index, about 1.530. This same substance appears in other preparations of the alumina-silica series and is probably glass."[1] It was assumed in the earlier work that this was merely sillimanite glass that had failed to crystallize but we found that even when the mass was treated in such a manner that crystals several millimeters long were formed, the interstitial glass was as plainly present, in fact, was more definitely determinable as glass. Now it is contrary to all our experience with any compound which crystallizes readily enough to form large crystals that some of the compound should persistently retain the glassy condition. We were led to conclude, therefore, that the glass did not have the same composition as the crystals and, from its low refractive index and its refusal to crystallize, that it must be rather highly siliceous. If the glass is more siliceous than the total composition of the mass then the crystals must obviously be more aluminous. Acting on these indications we proceeded to determine the composition of the crystals by making up mixtures with more alumina than the 1:1 ratio. In accordance with our expectations it was found that with addition of alumina the amount of crystals increased and that of glass diminished until at the composition $3Al_2O_3.2SiO_2$ the glass had entirely disappeared and the whole preparation consisted of crystals identical with those in the 1:1 preparation. Unquestionably, then, these crystals have the composition $3Al_2O_3.2SiO_2$ and are not sillimanite at all, although they show a very remarkable similarity with sillimanite in optical and crystallographic properties, a fact which will be brought out more fully at a later point.

FIG. 3.—Corundum crystal (combination of base and rhombohedron) from preparation of composition $Al_2O_3.SiO_2$ cooled slowly from 1900°C to 1810°C and then quenched.

Method of Investigation

These preliminary observations showed that revision of existing con-

[1] Shepherd, Rankin and Wright, *op. cit.*, 325.

cepts of the relations of alumina and silica at high temperatures was necessary. We, accordingly, proceeded to investigate systematically various mixtures covering the whole range of compositions. The method of quenching was adopted for the reason that it permits the determination of the phases present in any mixture at any temperature. For temperatures up to 1750°C we had the advantage over the earlier investigators of the use of a furnace wound with a wire of platinum 80%, rhodium 20%, constructed by our colleague, H. S. Roberts. In this furnace ordinary quenching experiments can be conducted under very favorable conditions and the temperature can be measured with a platinum-platinum rhodium thermocouple. For temperatures above 1750° an iridium tube furnace was used and the temperature measured optically. Such a furnace is not so well adapted for quenching work as could be desired but we found it possible to hold the temperature constant within a range of 8° to 10° and then to cool the charge rapidly by quick removal from the furnace. Charges with more than 50% alumina are usually not cooled rapidly enough to quench in the stricter sense of the term, but any new crystals formed during cooling are, in general, very minute as compared with the larger crystals formed during the period of constant temperature in the furnace and the two are thus distinguishable under the microscope. At its worst the method has distinct advantages over the method of observing the temperatures at which heat effects occur, for too often in such work the nature of the change of phase causing the heat effect can only be surmised.

The thermocouple used to measure temperatures below the melting point of platinum was calibrated at the anorthite point and the platinum point. The optical pyrometer employed was a Leeds and Northrup equipment which had been calibrated by the Bureau of Standards. To obtain constancy of conditions in our own work we matched the filament against a disc of magnesia on which the iridium foil containing the charge rested. In each run a small piece of platinum was placed on the magnesia disc alongside the charge and its melting observed as the temperature was raised. Working thus we were able to duplicate the platinum point within ±5°. The small deviation from the standard value at this point was used as a correction to the standard curve.

The charges were made up from specially purified precipitated alumina and quartz. These were ground together in the desired proportion and heated at the highest temperature attainable in the Fletcher gas furnace, a temperature in the neighborhood of the melting point of platinum. The charge was then ground and returned to the furnace, heating with subsequent grinding being repeated five times. The microscope then showed the charge to be either a single homogeneous phase, or to have its constituent phases uniformly distributed. Samples of these charges

were then used for the controlled runs in the iridium and platinum-rhodium furnaces.

Discussion of Equilibrium Diagram

The most noticeable feature of the equilibrium diagram, Fig. 4, is that $3Al_2O_3.2SiO_2$ is the only compound stable at these high temperatures. We have already presented our preliminary results fixing the composition of this compound, but the diagram serves to emphasize these findings. The $3Al_2O_3.2SiO_2$ preparation is a homogeneous aggregate of crystals of one kind at all temperatures up to 1810°C, where it begins to melt. A slight excess of alumina over the 3:2 ratio renders the charge inhomogeneous, corundum appearing in addition to the 3:2 compound. A slight

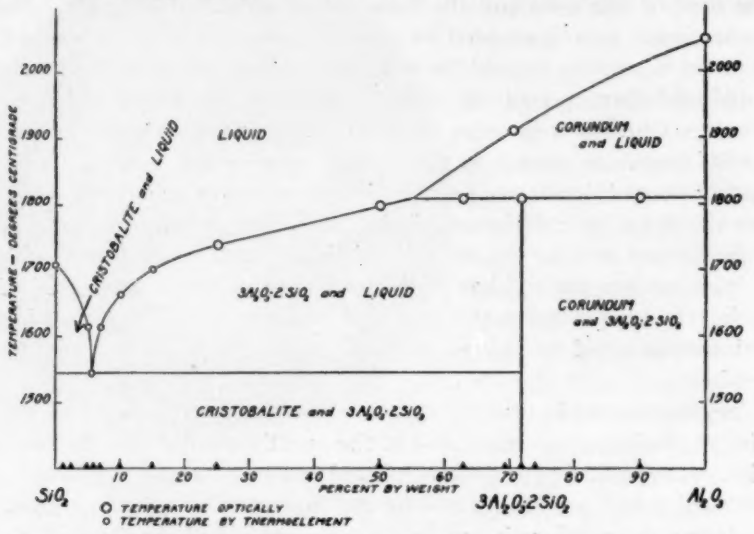

FIG. 4.—Equilibrium diagram of the system: $Al_2O_3.SiO_2$. After Shepherd, Rankin and Wright.

excess of silica brings in a little cristobalite below 1545°C and a little glass (liquid) above that temperature. The 1:1 preparation, $Al_2O_3.SiO_2$, is in no respect unique but is like all those that contain an excess of silica over the 3:2 ratio. It consists of the 3:2 compound with cristobalite below the eutectic, 1545°, and of the same compound with liquid above 1545° (and below 1810°).

Only one eutectic occurs, that between $3Al_2O_3.2SiO_2$ and cristobalite. There is no eutectic between $3Al_2O_3.2SiO_2$ and corundum for the reason that the 3:2 compound melts incongruently, breaking up into corundum and liquid, at 1810°. Only when the temperature is raised to about 1920° does the corundum finally disappear and a mixture of the composition of the 3:2 compound is then completely molten.

The breaking-up of $3Al_2O_3.2SiO_2$ into corundum and liquid at 1810° is exhibited in all preparations extending over as far as those containing only 55% Al_2O_3. This range includes the 1:1 ratio (63% Al_2O_3) so that a mixture of that composition, while it consists as it approaches 1810° of liquid and crystals of $3Al_2O_3.2SiO_2$, experiences, at this temperature, an abrupt increase in the quantity of liquid accompanied by formation of a little corundum. It was this sudden formation of liquid that gave the heat effect at 1810° that was regarded in the earlier work as fixing the melting point of a 1:1 compound, and it was the same heat effect obtained in slightly more aluminous mixtures at the same temperature, that was regarded as the result of melting of the eutectic between a 1:1 compound and corundum.

TABLE Ia

RESULTS OF RUNS IN PLATINUM-RHODIUM RESISTANCE FURNACE. TEMPERATURES MEASURED WITH THERMOELEMENT

Composition Weight per cent Al_2O_3	SiO_2	Temperature, °C	Time, minutes	Result
		Liquidus of Cristobalite		
5	95	1611	50	Glass and cristobalite
5	95	1618	50	All glass
				Liquidus 1615° ± 5°
		Eutectic—Composition and Temperature		
5	95	1542	120	Crystalline
6	94	1542	120	Crystalline
7	93	1542	120	Crystalline
				Below eutectic
5	95	1546	40	Cristobalite and glass
6	94	1546	40	$3Al_2O_3.2SiO_2$ and glass
7	93	1546	40	$3Al_2O_3.2SiO_2$ and glass
				Above eutectic
Composition of eutectic $5^1/_2$% Al_2O_3; $94^1/_2$% SiO_2.				
Temperature of eutectic 1545° ± 5°.				
		Liquidus of $3Al_2O_3.2SiO_2$		
7	93	1608	40	$3Al_2O_3.2SiO_2$ and glass
7	93	1614	40	Very rare crystals of $3Al_2O_3.2SiO_2$ in glass
				Liquidus 1615° ± 5°
10	90	1663	60	Very rare crystals of $3Al_2O_3.2SiO_2$ in glass
10	90	1667	30	All glass
				Liquidus 1665° ± 5°
15	85	1700	30	$3Al_2O_3.2SiO_2$ and glass
15	85	1703	30	Very rare crystals of $3Al_2O_3.2SiO_2$ in glass
				Liquidus 1705° ± 5°

The Compound $3Al_2O_3.2SiO_2$[1]

Some excellent crystals of the $3Al_2O_3.2SiO_2$ compound have recently been prepared in the laboratory of the Corning Glass Works. After experiments in the fusion of alumina-silica mixtures in an arc, crystals were found protruding into pipes in the consolidated product. They were thought to be artificial sillimanite, $Al_2O_3.SiO_2$, but when they were brought to our attention we were able to state from the results of our work that crystals formed at such temperatures could be nothing but the $3Al_2O_3.2SiO_2$ compound. Analyses were accordingly made in the Corning Laboratory and the results bore out our prediction. The protruding crystals

TABLE Ib

RESULTS OF RUNS IN IRIDIUM FURNACE. TEMPERATURE MEASURED WITH OPTICAL PYROMETER

Composition Wt. per cent Al_2O_3	Composition Wt. per cent SiO_2	Mol. ratio Al_2O_3	Mol. ratio SiO_2	Temperature, °C	Time, minutes	Result
Liquidus of $3Al_2O_3.2SiO_2$						
25	75	..	..	1753	6	All glass
25	75	..	..	1728	6	$3Al_2O_3.2SiO_2$ in large amount + glass
						Liquidus 1740° ± 13°
50	50	..	..	1800	10	Rare crystals of $3Al_2O_3.2SiO_2$ in glass
						Liquidus 1800° ± 10°
Temperature of the Invariant Point of $3Al_2O_3.2SiO_2$-Corundum-liquid						
62.9	37.1	1	1	1815	25	Glass + corundum
69.3	30.7	4	3	1817	3	$3Al_2O_3.2SiO_2$ + glass + corundum
71.8	28.2	3	2	1804	10	$3Al_2O_3.2SiO_2$
				1817	3	$3Al_2O_3.2SiO_2$ + glass
75	25	..	..	1803	5	Corundum + $3Al_2O_3.2SiO_2$ + very little glass
				1817	3	Corundum + glass
90	10	..	..	1804	10	$3Al_2O_3.2SiO_2$ + corundum. No glass
				1817	10	Corundum + $3Al_2O_3.2SiO_2$ + glass
Temperature of invariant point 1810° ± 10°						
Liquidus of Corundum						
69.3	30.7	4	3	1912	12	All glass
71.8	28.2	3	2	1912	12	Corundum + glass
						At 1912° ± 10° the liquidus lies between these compositions, *i. e.*, at 70.6% Al_2O_3 ± 1.3%.

[1] Since this paper was written we have discovered crystals of the $3Al_2O_3.2SiO_2$ compound in natural rocks from the Island of Mull. We propose the name *mullite* to designate the compound in a forthcoming paper in the *Journal of the Washington Academy of Sciences* where this natural occurrence of the mineral is described.

were broken off and thus obtained free from matrix or foreign material of any kind and therefore constitute particularly good material for analysis. The results, for which we are indebted to J. T. Littleton, Jr., are given in Table I.

TABLE II

ANALYSES OF CRYSTALS OF THE $3Al_2O_3.2SiO_2$ COMPOUND MADE IN LABORATORY OF THE CORNING GLASS WORKS

	I	II	$3Al_2O_3.2SiO_2$	$Al_2O_3.SiO_2$
SiO_2	27.60	27.35	28.2	37.1
Al_2O_3	73.16	72.87	71.8	62.9
TiO_2	none	none	..	..
Fe_2O_3	trace	trace	..	..
	100.76	100.22	100.0	100.0

Some of these crystals were very kindly turned over to us for examination. They are clear, transparent, colorless needles several millimeters long and upwards of a millimeter in diameter, with square cross-section but without terminal faces. Goniometric measurements on two crystals, A and B, gave the following results. (Table III.)

TABLE III

PRISM ANGLE OF CRYSTALS OF $3Al_2O_3.2SiO_2$

A	B	Mean	
90° 43′	90° 48′		
89° 13′	89° 22′	$110 \wedge \bar{1}10$	$110 \wedge 1\bar{1}0$
90° 52′	90° 46′	90° 47′	89° 13′
89° 10′	89° 06′		

The compound $3Al_2O_3.2SiO_2$ was prepared by Sainte-Claire Deville and Caron[1] as long ago as 1865. They passed SiF_4 over calcined alumina at a high temperature and obtained crystals which had the composition given under I and II, Table IV.

TABLE IV

ANALYSES OF THE $3Al_2O_3.2SiO_2$ COMPOUND BY EARLIER INVESTIGATORS

	I	II	III	IV	V	$3Al_2O_3.2SiO_2$
	Deville		Vernadsky	Cox		
SiO_2	29.1	29.5	29.7	30.07	28.89	28.2
Al_2O_3	70.9	70.2	70.3	69.93	71.11	71.8

Vernadsky in 1890 separated from Sèvres porcelain sillimanite-like crystals which proved on analysis to have the composition given under III,[2] Table IV.

[1] *Ann. Chim. Phys.*, **5**, 114(1865).

[2] *Bull. Soc. Min. Fr.*, **13**, 270 (1890).

Recently Cox separated and analyzed crystals formed in a fire clay "exposed to a very high temperature for many weeks."[1] His results are given under IV and V, Table IV.

Vernadsky concluded that Deville's results and his own placed the composition of the crystals at $11Al_2O_3.8SiO_2$, and Cox accepts this conclusion for his own. It is true that all the analyses point to a composition of the material analyzed slightly more siliceous than $3Al_2O_3.2SiO_2$, though one of Cox's deviates very little in that direction. Nevertheless the material is in all cases such that it could scarcely fail to be contaminated in some degree with siliceous matter. Moreover, we have examined the crystals in various porcelain and fire-clay products and have also made some after the method of Deville and find that their refractive indices are identical with those of the pure $3Al_2O_3.2SiO_2$. We believe, therefore, that in all the cases the crystals have that composition.

The properties of the compound are remarkably constant, whatever the conditions under which it is made, so long as certain oxides which may be taken into solid solution are absent. No measurable variation of refractive indices can be detected in the crystals whether they are grown in a liquid containing 90% SiO_2, 10% Al_2O_3, or whether they are formed in the presence of excess corundum. Likewise there is no variation between crystals formed by sintering oxides at a comparatively low temperature or by fusing the mass in an electric arc. The properties of the compound are given in Table V below and compared with those of sillimanite from Delaware County, Pennsylvania.

TABLE V

PROPERTIES OF $3Al_2O_3.2SiO_2$ AND OF SILLIMANITE

		$3Al_2O_3.2SiO_2$	Sillimanite
Crystal system		Orthorhombic	Orthorhombic
Prism angle $(110 \wedge 1\bar{1}0)$		89° 13′	88° 15′
Cleavage		//010	//010
Optic orientation		$\dot{c} = \gamma$ and $\bar{b} = \alpha$	$\dot{c} = \gamma$ and $\bar{b} = \alpha$
Refractive indices	γ	1.654	1.677
	α	1.642	1.657
Axial angle	2V	+45°–50°	+25°

Natural Sillimanite

The mineral sillimanite, $Al_2O_3.SiO_2$, occurs in nature in crystals with a nearly square prism angle, with one cleavage diagonal to the prism to which the plane of the optic axes is parallel and the elongation is positive. In all these respects it is identical with the artificial $3Al_2O_3.2SiO_2$ compound. Only when precise quantitative measurements of optical and crystallographic constants are made can the two be distinguished and even then

[1] A. H. Cox, *Geol. Mag.*, Dec. 6, **5**, 61(1918).

they are found to be very closely related. The detailed measurements of sillimanite from Delaware County, Pennsylvania are given in Table V, where they may be compared with those of $3Al_2O_3.2SiO_2$. Probably no other example is known of two distinct compounds of the same oxides that are so nearly alike in properties. So similar are they that, after having established the composition of our artificial compound beyond any possibility of question, we were led to doubt whether the composition of the natural mineral had been established. All the available analyses were old, so we selected very pure material which proved on examination under the microscope to be nearly free from foreign matter of any kind, and an analysis of this was kindly made for us by E. G. Zies of this laboratory. Our doubts were promptly dispelled, for the analysis, given below under I, Table VI, shows that the mineral undoubtedly corresponds with the 1:1 composition. After this analysis had been made another new analysis of a very pure sillimanite was published which shows a nearly identical composition (Table VI, II).

TABLE VI

COMPOSITION OF NATURAL SILLIMANITE

	I	II	III
SiO_2	37.08	36.70	37.1
Al_2O_3	63.11	62.73	62.9
Fe_2O_3	0.09	.63	....
	100.28	100.06	100.0

I. Sillimanite from Delaware County, Pennsylvania, U. S. National Museum No. 9752, E. G. Zies, analyst. TiO_2 is less than 0.01%.

II. Sillimanite from Romaine, Quebec.[1] E. W. Todd, analyst.

III. Theoretical $Al_2O_3.SiO_2$.

These two excellent analyses confirm the accepted conclusion as to the composition of sillimanite and emphasize that it is a compound altogether distinct from $3Al_2O_3.2SiO_2$. It might be supposed that between two compounds so nearly identical in properties there would be a series of solid solutions intermediate in composition. If this were true there would also be a gradation of properties. However, the existing analyses of natural sillimanite never show a significant excess of alumina over the 1:1 ratio nor have we succeeded in preparing, in any iron-free mixture, crystals with properties that differ from those of the pure $3Al_2O_3.2SiO_2$ compound.

Behavior of Natural Sillimanite on Heating

While all the evidence shows that the 1:1 compound has no stable existence at high temperatures, nevertheless natural sillimanite can be heated

[1] Walker and Parsons, Univ. of Toronto Studies, *Geol. Series* **16**, 36(1923).

for long periods at any temperature below 1545° without changing. We heated some for 6 days at 1350° but the microscope failed to reveal any evidence that it had begun to break up into the $3Al_2O_3.2SiO_2$ compound and free silica, which mixture of phases is shown by our results to represent the true equilibrium condition for this temperature. As soon as a temperature of 1545° (eutectic between $3Al_2O_3.2SiO_2$ and SiO_2) is passed, however, the sillimanite begins to be affected, forming crystals of $3Al_2O_3.2SiO_2$ and a highly siliceous liquid (about 95% SiO_2). Above this temperature natural sillimanite behaves precisely like a 1:1 artificial mixture, that is, the liquid increases and the crystals of $3Al_2O_3.2SiO_2$ diminish in quantity until at 1810° there is an abrupt increase in the amount of liquid as a result of the break-up of the $3Al_2O_3.2SiO_2$ compound into corundum and liquid.

At temperatures not far above the eutectic (1545°), crystals of natural sillimanite appear to change less readily than the 1:1 artificial mixture. This apparent difference is due to the contrasted structure of the two materials. The 1 : 1 mixture, even before being raised to a temperature above the eutectic, already consists of two phases, cristobalite and $3Al_2O_3.2SiO_2$, in random arrangement. When this aggregate is heated to a temperature above the eutectic the cristobalite disappears and the liquid formed constitutes a matrix for the minute prisms of $3Al_2O_3.2SiO_2$, still, of course, in random arrangement. This type of structure is well displayed in the photomicrograph, Fig. 5. On the other hand, natural sillimanite is a single, pure, crystalline phase and therefore perfectly homogeneous. Moreover the difference in crystal structure between sillimanite and $3Al_2O_3.2SiO_2$ is so slight that when liquid and crystals of $3Al_2O_3.2SiO_2$ are formed from sillimanite the new-formed crystals are coextensive with the original grains of sillimanite and of identical orientation. The liquid occurs as minute pellets and filaments in the large grains of $3Al_2O_3.2SiO_2$. The structure is shown in the photomicrograph, Fig. 6, which is to be compared with Fig. 5. Mechanically the aggregate formed from natural sillimanite is probably the stronger because the crystalline phase is the external phase, whereas the liquid phase is external in any synthetic 1:1 aggregate. At temperatures far above 1545°, however, where the amount of liquid is

FIG. 5.—Photomicrograph showing structure of high-grade fire-clay cylinder heated at 1600°C–1700C° for several hours. Prismatic crystals of $3Al_2O_3.2SiO_2$ embedded in glass.

much increased, the difference between the two types of material is not so great but it is still noticeable at 1750°.

We thus see that natural sillimanite may, perhaps, have certain advantages over an artificial 1 : 1 mixture in a mechanical way; though not fundamentally any more refractory, but whether this difference observed in our small charges would be sustained in actual use under load our work does not enable us to state.

Alumina-Silica Refractories

The behavior of material containing alumina and silica in the 1 : 1 ratio has been discussed rather fully in the foregoing because it has hitherto been regarded as the most refractory mixture. We wish to emphasize, however, that the 1 : 1 proportion does not give the most refractory material. The $3Al_2O_3.2SiO_2$ mixture is far superior in this respect though it is equaled by any mixture with an excess of alumina over this proportion, all of which mixtures begin to melt only at 1810°C. The slightest excess of silica over $3Al_2O_3.2SiO_2$ is sufficient to cause a beginning of melting at 1545°C, the amount of liquid formed at any temperature being, of course, proportional to the amount of excess silica.

FIG. 6.—Photomicrograph showing structure of powdered natural sillimanite after heating at 1700° for 3 hours. Each grain of sillimanite, originally clear and transparent, is changed to crystalline $3Al_2O_3.2SiO_2$ in which are embedded pellets of a highly siliceous glass.

It is to be noted, however, that formation of some liquid at these relatively low temperatures may even be advantageous in some of the uses to which refractories are put. In the absence of other bonding material the liquid would serve as a bond which, by reason of its very high content of silica, is excessively viscous and, therefore, does not lead to ready deformation of the mass. Occurring at it does as the matrix of interlocking needle crystals of $3Al_2O_3.2SiO_2$, the material as a whole is quite strong unless the temperature is raised to such a point that the liquid is present in considerable amount, which temperature depends of course on the total composition and is highest for those compositions which approach $3Al_2O_3.2SiO_2$.

Moreover, the interstitial liquid ordinarily does not recrystallize on cooling but forms a glass which, since it is so highly siliceous, tends to endow the whole mass with the desirable characters of silica glass, principally resistance to fracture upon sudden heating and cooling. These remarks apply with special force to the pure alumina-silica mixtures. Where small amounts of alkalies, lime, magnesia, etc., are present all of these enter into the liquid which is very much increased in amount and loses much of its excellence as a glass because not so siliceous.

Broadly speaking, then, the refractory power of alumina-silica mixtures increases directly with the alumina content, omitting, of course, those mixtures with more than 95% silica. There is no maximum melting point anywhere in the series. To be sure all mixtures between SiO_2 and the compound begin to melt at the same temperature but the amount of liquid formed at any temperature decreases as the alumina content increases and becomes vanishingly small as the compound is approached, so the above generalization remains substantially true.

The compound itself, $3Al_2O_3.2SiO_2$, has very marked refractory power and it is noteworthy that one of the available analyses of Marquardt porcelain, that of an outer pyrometer tube, corresponds, barring its minor ingredients, fairly closely with the 3 : 2 compound, to which fact it no doubt owes its special refractory power. The analysis[1] is given below in Table VII.

TABLE VII

COMPOSITION OF REFRACTORY TUBE

	Pyrometer tube	$3Al_2O_3.2SiO_2$
SiO_2	29.75	28.2
Al_2O_3	66.52	71.8
Fe_2O_3	0.65	....
TiO_2	0.43	....
CaO	0.66	....
MgO	0.26	....
Na_2O	0.70	....
K_2O	0.92	....
H_2O	0.31	....
	100.20	100.00

It may be remarked here, too, that if natural sillimanite is to be used as a refractory the presence of some corundum in it, far from being detrimental, is a decided advantage.

Supposed Sillimanite in Various Wares

A great many investigators, including one of us, have regarded as sillimanite the needle-shaped crystals that form in so many kinds of ceramic

[1] *Trans. Amer. Ceram. Soc.*, **15**, 607(1913).

wares and that resemble natural sillimanite to such a remarkable degree. We have examined materials in great variety, representing a wide range of compositions and treatments, including glass pots, tank blocks, special refractories, and "fused sillimanite." In all of these we have found the crystals to be $3Al_2O_3.2SiO_2$. In order to determine the crystals with certainty it is necessary to be able to measure the refractive indices. This presents some difficulty in the ordinary materials since they contain these crystals as minute needles completely surrounded by glass. However, by putting some of the powdered material in cold HF for a few hours the matrix is completely removed and the crystals can be transferred to immersion liquids for measurement of refractive indices. By careful handling, the refractive indices of the merest fibers can thus be measured. Working in this manner we found that in nearly every material we examined, whether it was a glass pot, "sillimanite" made by the Malinite process, "sillimanite" spark plugs or what not, the crystals have properties that do not differ significantly from those of pure $3Al_2O_3.2SiO_2$.[1] The first exception found was some material labeled "sillimanite from pot crowns" which we obtained through the kindness of Donald W. Ross of the Findlay Clay Pot Company. It was described as coming from the crowns of covered pots which had been in service for several months in commercial glass furnaces at temperatures from 1250° to 1450°. The crystals in this material were found to have the following indices, $\gamma = 1.672$ and $\alpha = 1.653$. These values are very much higher than those of $3Al_2O_3.2SiO_2$ and not very different from those of sillimanite. For a time in the early stages of our investigation we thought these crystals were sillimanite, $Al_2O_3.SiO_2$, but the failure of repeated attempts to make crys-

TABLE VIII

CHEMICAL ANALYSIS OF CRYSTALS OF $3Al_2O_3.2SiO_2$

	I	II
SiO_2	29.36	28.2
Al_2O_3	69.05	71.8
Fe_2O_3	0.86	....
TiO_2	1.12	....
MgO	0.10	....
	100.49	100.0

I. Crystals from pot crowns. Analyst N. L. Bowen. Fe_2O_3 and TiO_2 by M. Aurousseau.

II. Theoretical $3Al_2O_3.2SiO_2$.

[1] The porcelain of a recent type of Champion spark plug contains abundant crystals of corundum as well as of the 3:2 compound indicating a burning temperature within the corundum field. This is not necessarily above 1810°C for the presence of any foreign oxides that such material may contain would lower the temperature of the corundum field.

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tals with such properties in pure alumina-silica mixtures led us to conclude that they owed their higher refractive indices to the presence of other oxides acquired from impurities in the clay. Accordingly we separated a quantity of these crystals from their matrix by means of cold HF, obtaining clean sharp crystals nearly free from matrix or foreign material of any kind. This material was analyzed with the results given in Table VIII. The crystals are plainly the 3:2 compound containing a considerable amount of iron and titanium in solid solution.

We thus encounter the very unfortunate complication that crystals of the 3:2 compound may have their properties changed in such a way that they are practically indistinguishable from sillimanite by optical means. To be sure, the indices of the pot crown crystals are still distinctly lower than those of natural sillimanite, but presumably $3Al_2O_3.2SiO_2$ crystals are capable of further contamination of the same sort and it would take but little more to give them maximum and minimum indices (and, of course, birefringence) indistinguishable from those of sillimanite. This fact is well brought out graphically in Fig. 7 where the curves of indices of iron-bearing $3Al_2O_3.2SiO_2$ crystals are shown. The curves have been extrapolated a short distance so that the end points correspond with the indices of hypothetical $3Al_2O_3.2SiO_2$ crystals containing somewhat less than 3% Fe_2O_3 + TiO_2. These end points also agree sensibly with the indices of natural sillimanite, $Al_2O_3.SiO_2$, from Delaware County, Pennsylvania, which contains only 0.09% Fe_2O_3 and practically no TiO_2.

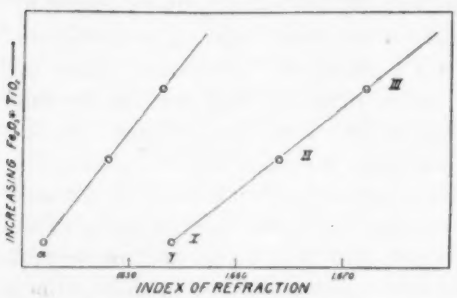

FIG. 7.—Curves of refractive indices of crystals of $3Al_2O_3.2SiO_2$ containing Fe_2O_3 and TiO_2. I, pure $3Al_2O_3.2SiO_2$, II, Eitel's crystals, III, pot crown crystals with 2 per cent Fe_2O_3 + TiO_2. Points at extrapolated terminations of curves agree very closely with indices of natural sillimanite from Delaware County, Pennsylvania.

We are able to place on this plot one other example of $3Al_2O_3.2SiO_2$ crystals. These were not obtained from ceramic ware but were prepared by Eitel by an alumino-thermic method and their properties recorded by him.[1] He regarded them as sillimanite, but crystals prepared in such a manner could be nothing but $3Al_2O_3.2SiO_2$. Their indices (γ = 1.664, α = 1.648) are decidedly lower than those of sillimanite and somewhat higher than those of pure $3Al_2O_3.2SiO_2$, but both indices correspond well with those of crystals of this latter compound containing about 1% Fe_2O_3 (+TiO_2). Both iron and titanium were present in the raw materials

[1] W. Eitel, *Z. anorg. Chem.*, **88**, 173 (1914).

and the fact that the crystals are pleochroic shows that a significant amount has entered into their make-up.

We must emphasize again that this gradation of the properties of the $3Al_2O_3.2SiO_2$ crystals towards those of sillimanite is not due to any gradation of composition between these two compounds. Chemically, they are always distinct. Fortunately, too, the content of iron in the crystals formed in ceramic materials is, in the vast majority of cases, too small to lead to any confusion of these crystals with sillimanite if careful measurements are made.

It should be pointed out here that Vernadsky, whose preparation of $3Al_2O_3.2SiO_2$ we have already mentioned, also made material which he believed to be sillimanite by simple fusion together of alumina and silica.[1] Since our very numerous attempts to achieve this result cover the widest possible range of conditions we are thoroughly convinced that sillimanite cannot be prepared in such a manner and that the material prepared and analyzed by Vernadsky could not have consisted of homogeneous crystals of a single substance but must have been a mixture.

Sillimanite, according to our observations, does not form in any alumina-silica mixture at any temperature at which the crystals grow to a sufficient size to be determinable. Moreover, we have added various fluxes to alumina-silica mixtures in order to lower the temperature at which determinable crystals could be obtained and thus succeeded in growing such crystals at 1050°C, but they are always $3Al_2O_3.2SiO_2$. There is, no doubt, some temperature, presumably still lower, at which sillimanite is stable, for Nature has made it in abundance, but we have not succeeded in imitating her.

Nor have we found sillimanite in ceramic wares of any kind. The crystals in these are always $3Al_2O_3.2SiO_2$. This observation would seem to be in disagreement with the X-ray analysis of porcelain made by G. Shearer.[2] He subjected natural sillimanite and a piece of porcelain to such analysis using the powder method and obtained identical spectra. However, our colleague, Dr. Wyckoff, has kindly made similar powder photographs of our very pure sillimanite from Delaware County, Pennsylvania (analysis I, Table VI), and also of the clear, transparent, microscopically homogeneous crystals of $3Al_2O_3.2SiO_2$ (analyses, Table II), and has found that they give identical spectra. This is no place for a discussion of the significance of this observation. Suffice it to say here that the crystals contained in a ceramic ware cannot be established as sillimanite on the basis of X-ray analysis since this method fails to distinguish between that compound and $3Al_2O_3.2SiO_2$.

Summary

Corundum is frequently formed from shales and clays when these are

[1] *Bull. Soc. Min. Fr.*, **13**, 263(1890).

[2] *Trans. Ceram. Soc.*, **22**, 106(1923).

attacked by natural magmas or by artificial melts such as glasses even when there is plenty of silica present to form sillimanite. This setting-free of alumina as corundum suggested that sillimanite itself must melt incongruently, breaking up into liquid and corundum. The older work on the system: alumina-silica indicated a maximum, congruent melting point of sillimanite, but this was not as definite as could be desired and a reexamination of the system was therefore undertaken.

The present study has shown that there is only one compound of alumina and silica stable at high temperatures. This compound is chemically distinct from sillimanite, $Al_2O_3.SiO_2$, since it has the composition $3Al_2O_3.2SiO_2$, but its optical and crystallographic properties are very close to those of sillimanite. On account of this similarity of properties the crystals of the $3Al_2O_3.2SiO_2$ compound have been regarded as sillimanite in earlier work.

Since the only compound existing at high temperatures is the 3 : 2 compound, a synthetic mixture of the composition $Al_2O_3.SiO_2$ is always found to be inhomogeneous. As ordinarily obtained, by heating to a temperature of 1600° to 1700°C, it consists of crystals of $3Al_2O_3.2SiO_2$ and a highly siliceous glass.

Natural sillimanite though unstable at high temperatures, is very inert and suffers no change when heated for several days at any temperature below 1545°C, the temperature of the eutectic between cristobalite and $3Al_2O_3.2SiO_2$. Above this temperature sillimanite breaks up into crystals of $3Al_2O_3.2SiO_2$ and liquid.

The compound $3Al_2O_3.2SiO_2$ melts incongruently, breaking up at 1810°C into corundum and liquid. The field of corundum and liquid extends not only beyond the 3 : 2 compound but also beyond the composition of sillimanite so that if natural sillimanite or a synthetic mixture of the same composition are heated to a temperature slightly above 1810°C they form corundum and liquid.

The most refractory mixture of alumina and silica is not the 1 : 1 mixture as has been supposed hitherto, for such a mixture begins to show some formation of liquid at 1545°. A mixture of the composition $3Al_2O_3.2SiO_2$ is much more refractory since it begins to melt only at 1810°C.

The crystals of so-called sillimanite occurring in various kinds of ceramic wares are always crystals of the $3Al_2O_3.2SiO_2$ compound. In the presence of much Fe_2O_3 and TiO_2 the crystals may take these oxides into solid solution and their properties may then be changed in such a way that they are indistinguishable from sillimanite except by chemical analysis. Fortunately, in the vast majority of wares the amount of iron and titanium is small and the crystals of $3Al_2O_3.2SiO_2$ are readily identifiable as such by optical means alone.

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON

THE SIGNIFICANCE OF DRAFTS IN DOWN-DRAFT, COAL-FIRED KILNS[1]

By Ralph A. Sherman,[2] R. F. Lunger,[3] and W. E. Rice[4]

ABSTRACT

The fundamental laws of gas flow are applied to the movement of gases through down-draft kilns. Data on pressure conditions in four kilns are presented graphically. The cause of draft, the superiority of the down-draft over the up-draft kiln, the significance of stack draft, the relation of draft and excess air, features of kiln design, and the comparative merits of forced, induced and natural draft are discussed.

Introduction

Among the data taken during the course of the investigation of burning problems in the manufacture of refractories, conducted by the Bureau of Mines in coöperation with the Refractories Manufacturers Association, were pressure readings in the stack and at various points within the kiln on several of the kilns investigated. Although the readings were not taken for the purpose of determining the laws of the flow of gases in these kilns, they are sufficiently accurate to serve as a basis for a discussion of the significance of drafts in down-draft, coal-fired kilns.

The Cause of Drafts

Bricks are burned by passing hot gases formed by the combustion of a fuel, such as coal, through the mass of ware set in a kiln. To burn the coal, air must pass through the bed of fuel, the hot gases must overcome the resistance to their passage through the ware, and as the gases would be objectionable if discharged near the ground level, they must overcome the friction of the flues and a stack which discharges them at some height above the ground and surrounding structures.

Since gases move only from points of high to lower pressure it is necessary to establish a pressure difference between successive points along the path of the gases. The pressure difference may be established by several different means. A pressure greater than atmospheric may be established under the grates by means of a fan, or forced draft; a pressure less than atmospheric may be established in the kiln by means of a fan or steam jet in the stack forcing the gases out of the kiln, or induced draft; or the same condition may be obtained by the difference in the weights of the column of hot gases in the stack and of the column of cold air on the outside, or natural draft. The latter method, natural draft, was the method used on

[1] Published by permission of the Director, U. S. Bureau of Mines. Presented at Atlantic City Meeting, Feb., 1924.

[2] Assistant Physicist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

[3] Junior Fuel Engineer, Pittsburgh Experiment Station, U. S. Bureau of Mines.

[4] Computer, Pittsburgh Experiment Station, U. S. Bureau of Mines.

the four kilns studied in this investigation and is the method most commonly used on periodic kilns.

Natural Draft.—The creation of pressure difference by natural draft may be illustrated from the sketches of Fig. 1. A and B represent columns of a light gas such as a kiln stack filled with hot flue gas and surrounded by air, A being open at the top and closed at the bottom and B closed at the top and open at the bottom. If W is the weight of the column of air over A above the level M-M, I is the weight of the gases inside the column A, and O is the weight of a column of air on the outside of the same dimensions as A, then the pressure on the inside at the level N-N will be $W + I$ and on the outside at that level $W + O$. Then the difference is $(W + O) - (W + I) = O - I$.

In the column B, closed at the top and open at the bottom, the pressure on the outside at the level M-M is W and on the inside is $W + (O - I)$ and the difference is $W + (O - I) - W = O - I$. Therefore, the total available pressure acting on a column of gas when at rest is equal to the difference in the weights of the column of gas and a column of air of the same dimensions, and the available pressure per unit area is equal to the difference in the weights of a column of gas and a column of air of unit cross-section and of the same height.

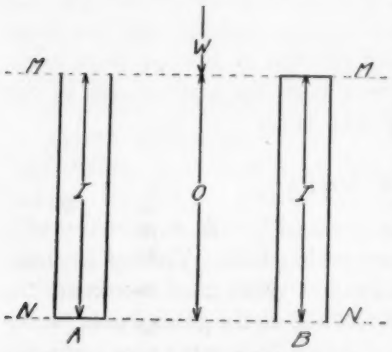

FIG. 1.—Cause of pressure difference between points within a column of light gas and the air outside.

As the density of a gas varies inversely as the absolute temperature the pressure difference will be greater, the greater the temperature difference between the hot gas and the air. Also, obviously, the pressure difference will be greater, the greater the height of the column.

If one leg of a U-tube filled with water be connected to a tube inserted into column A at the level N-N there will be a resultant difference in the water levels in the two legs equal to $0.192 \times (O - I)$ inch when O and I are expressed in pounds per square foot, 0.192 being the height of the water column in inches equal to a pressure of one pound per square foot.

It should be remembered that the reading obtained on a draft gage is the difference in the pressure of the gas inside and the air outside at the same level. It is immaterial whether the gage is placed above, at, or below this level, provided the temperature in the connecting tube equals that of the surrounding air. Thus, in B, Fig. 1, the pressure on the inside at the top M-M, $W + O - I$, is greater than the pressure at that level outside, W, but is less than the pressure at the bottom $W + O$.

When gage readings are taken at different levels, therefore, the pressure due to the weights of the columns between these levels must be considered.

Down-draft Versus Up-draft Kilns

The gases formed by the combustion of coal in the fire-boxes are divided by the ware into a great number of gas columns. Let us assume that the gases pass upward through these columns as in an up-draft kiln and that for some reason the ware in one column became hotter than in the others, then the gas in this column would give up less heat to the ware and would be hotter and hence lighter than the gases in the other columns and the force driving the gas through this column would become greater and greater as the temperature continued to increase. Conversely the temperature and pressure on the gas would tend to decrease in a column which had become cooled.

When the gases pass downward through the columns as in a down-draft kiln, if one column became hotter than others the force driving the gas down through this column would decrease and less gas would flow through this than through the other columns until the temperatures were equalized. Similarly, a greater force would act on a cool column until the temperatures were equalized. Thus, a much more uniform temperature may be secured in a down-draft than in an up-draft kiln.

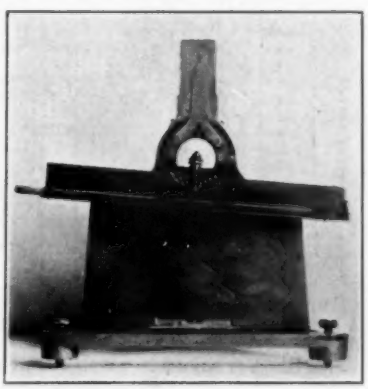

FIG. 2.—Inclined manometer.

Method of Reading Pressures

The pressure in the kilns and stack were read on a specially designed manometer connected by piping and rubber tubing to an open-end pipe inserted at the desired point at right angles to the probable path of the gas.

The manometer which is shown in Fig. 2 consists essentially of a glass U-tube so mounted that it may be inclined to any desired angle in order that small differences in pressure may make a large difference in the reading of the manometer. Gasoline of specific gravity 0.715 (water = 1) is used in the gage to further increase its sensitivity. Scales used with the various angles of inclination are so calibrated that the readings are obtained directly in inches of water. At the smallest angle of inclination the instrument is sensitive to one one-thousandth of an inch of water.

Hourly readings were taken in the flue leading to the stack and at other points at approximately 4-hour intervals throughout the length of the

burn. Readings were taken at the top of the kiln just inside the crown, inside the top and the bottom of the wicket and on some kilns in the ash-pit and in the furnace.

As the gases doubtless did not flow at all times at right angles to the pipe the pressure readings at times may have been higher or lower than the real static pressure. The pressure probably varied across any horizontal plane in the kiln and therefore the pressures read did not represent the average pressure across the kiln.

A much more accurate method of obtaining the true pressure reading is to use a pipe with a closed end with small openings, $\frac{1}{16}$ inch or less, drilled in diametrically opposite sides of the pipe, the pipe being so inserted that the plane through the openings is at right angles to the direction of the gas flow.

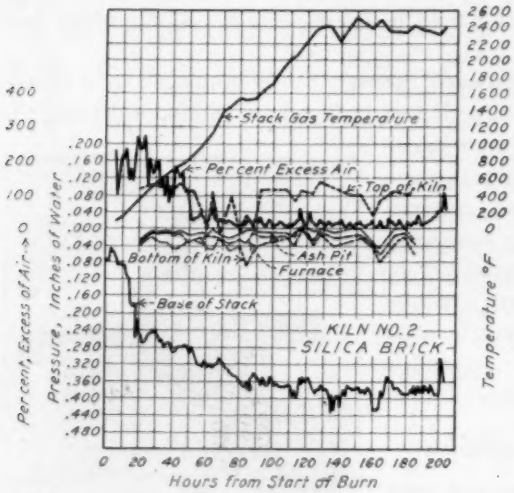

FIG. 3.—Variations in pressures at various points during burn.

The readings obtained on 4 kilns are plotted in Figs. 3, 4, 5, and 6 as ordinates, the hours from the beginning of the burn as abscissas. The stack gas temperatures and percentages of excess air in the gases are also shown. A sectional elevation of the kiln and a plan of the flue system is shown on each figure. The kilns are referred to as numbers 2, 5, 6, and 7, these being the numbers given the kilns in the investigation.

The pressure at the top of Kiln 2 was, with the exception of a few erratic readings, greater than that of the air at that level. The pressure in the ash-pit was generally less than that of the air at that level. If the difference in the pressure of the air at the two levels were not considered it would seem that gases were moving in the direction of a point of higher pressure.

This may be made clearer by a specific example. At the ninety-second hour in Fig. 3 the pressure in the ashpit was 0.008 inch of water less and at the top of the kiln the pressure was 0.092 inch greater than the pressure of the air at the respective levels. The temperature of the air was 75°F and that of the gases will be assumed to have been 2400°F. Assuming the gases inside the kiln to have the same density as the air at the same tem-

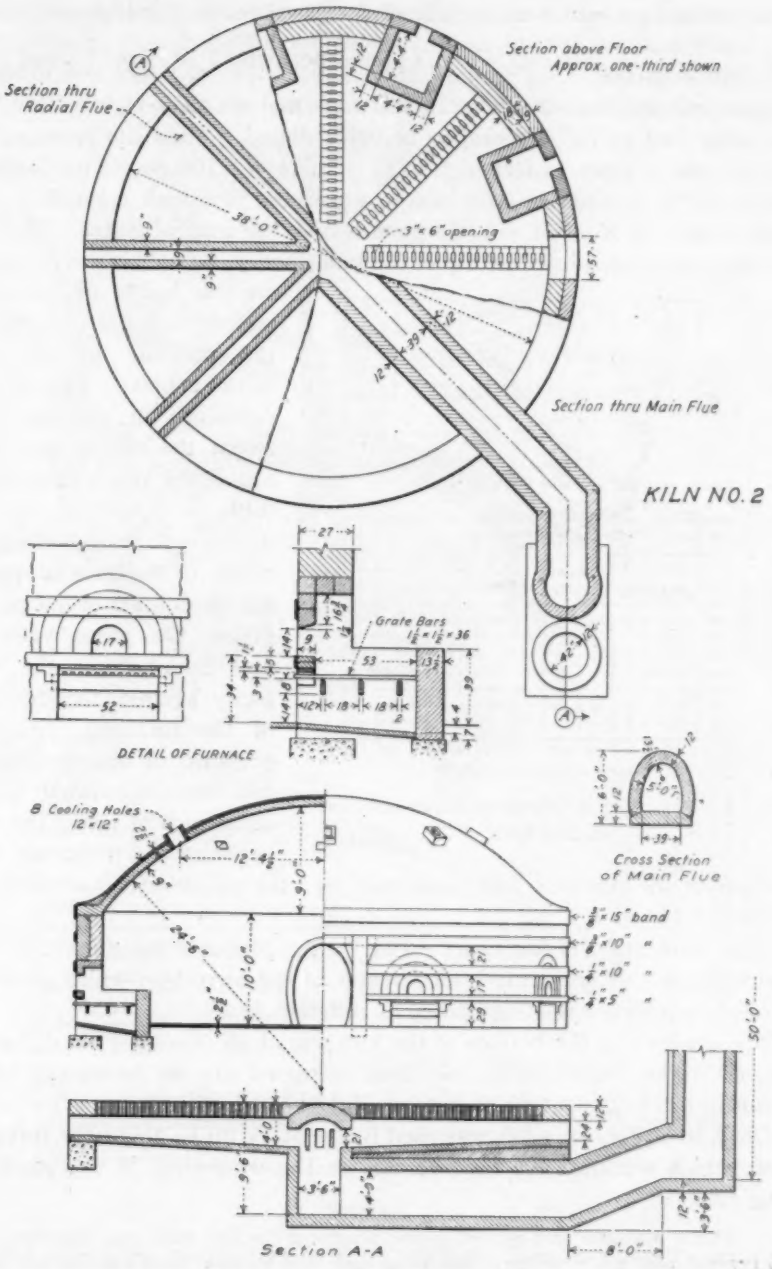
Section above Floor
Approx. one-third shown
Section thru
Radial Flue
38'-0"
3"x 6" opening
Section thru Main Flue
KILN NO. 2
Grate Bars
DETAIL OF FURNACE
8 Cooling Holes
12 x 12"
Cross Section
of Main Flue
Section A-A
8'-0"
50'-0"

FIG. 3a.

perature and pressure,[1] the weight of the gases per unit volume at 2400° was $\frac{460 + 32}{460 + 2400} \times 0.0807 = 0.014$ pound per cubic foot, 0.0807 being the weight per cubic foot at 32°. In the same manner the weight of the air per cubic foot at 75° is found to be 0.074 pound. Then the pressure of the column of gases 14 feet high is $14 \times 0.014 = 0.196$ pound per square foot or $0.192 \times 0.196 = 0.038$ inch of water and of the air column of the same height $14 \times 0.074 = 1.036$ pounds or 0.199 inch of water. If p is the pressure of the air at the top of the kiln, then $p + 0.092$ is the pressure on the inside at the top and $p + 0.199 - 0.008$ is the pressure of the air in the ashpit. The actual difference in pressure between the ashpit and the top of the kiln is then $(p + 0.199 - 0.008) - (p + 0.092) = 0.099$ inch of water which is the force supporting the column of hot gases, giving the gases velocity and maintaining the velocity against the friction of the fuel bed. As the pressure of the hot gases has been calculated to be 0.038 inch of water the net pressure to overcome the friction of the fuel bed and walls and give the gas velocity was $0.099 - 0.038 = 0.061$ inch.

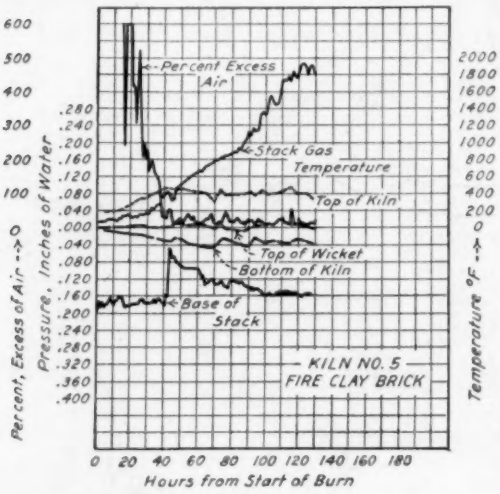
Percent Excess Air
Stack Gas Temperature
Top of Kiln
Top of Wicket
Bottom of Kiln
Base of Stack
KILN NO. 5
FIRE CLAY BRICK
Percent Excess of Air
Pressure, Inches of Water
Temperature °F.
Hours from Start of Burn
0 20 40 60 80 100 120 140 160 180
600 500 400 300 200 100 0
.280 .240 .200 .160 .120 .080 .040 .000 .040 .080 .120 .160 .200 .240 .280 .320 .360 .400
2000 1800 1600 1400 1200 1000 800 600 400 200 0

FIG. 4.—Variations in pressures at various points during burn.

This calculation is not exact owing to the probable inaccuracy of the assumptions. However, it is an example of the correction which must be applied to pressure readings taken at different levels.

The pressure in the bottom of the kiln was at all times less than that of the air. The depression in the stack increased due to increasing temperature of the gases to a maximum of 0.440 inch of water.

On Kiln 5 (Fig. 4), a fan was used in the stack up to about the fortieth hour which accounts for the decrease in the depression in the stack at that time.

[1] This is obviously not correct as the density of the dry gases was probably 2 to 5% greater than that of the air. But as the gases also contain steam which is less dense than air any assumption as to the density would not be exact and no great error for the present purpose is introduced in assuming their densities to be the same.

In Kiln 6 (Fig. 5) the pressure at the top of the wicket was greater than atmospheric during practically the entire burn and the pressure in the bottom of the kiln was greater than atmospheric up to the fortieth hour. The stack was dampered several times toward the end of the burn.

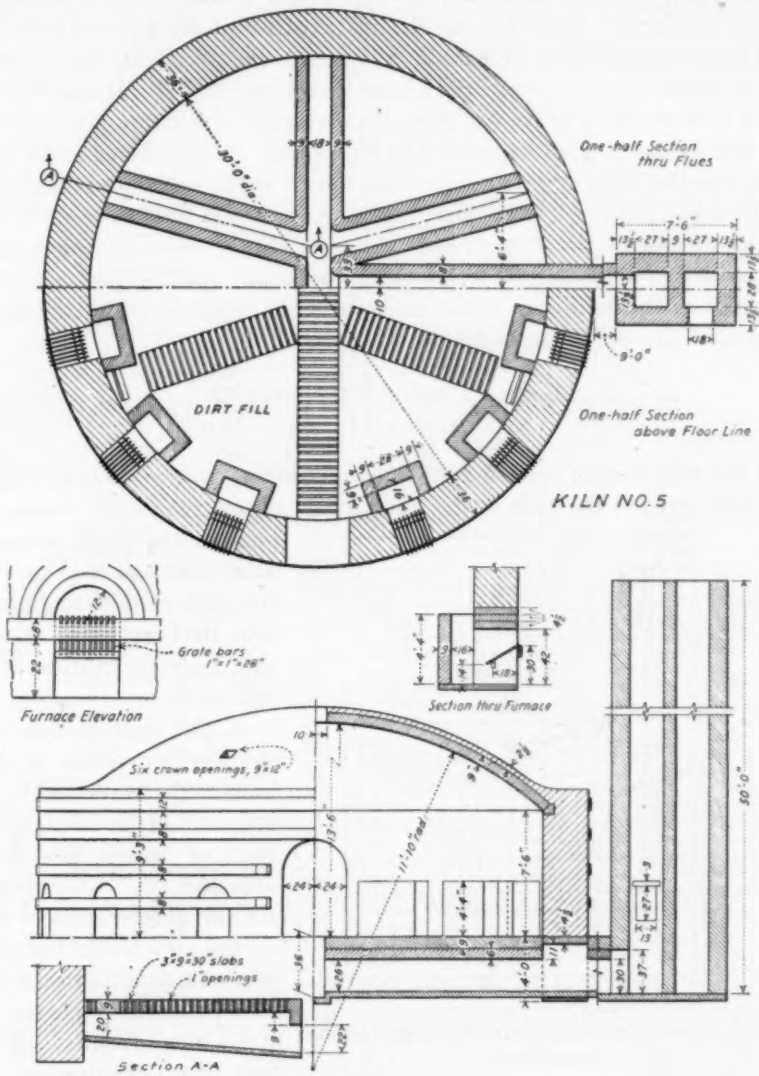

FIG. 4a.

The depression in the stack of Kiln 7 (Fig. 6), increased rapidly owing to the rapid rise in stack temperature. The pressure at the top of the wicket was less than atmospheric from about the thirtieth hour to the seventieth

hour when the stack was dampered and the pressure in the bottom of the kiln was less than atmospheric throughout the burn.

Significance of Stack Draft

The maximum depression in the stack attained during the burn on 0.32 inch of water; and on Kiln 7, 0.34 inch. (See Figs. 3*a*, 4*a*, 5*a*, 6*a*.) These figures do not necessarily mean that more coal per square foot of grate area could be burned in the kiln with 0.44 inch depression than in the one with 0.20 inch depression in the stack. These values mean that there was this drop in pressure between the air at the grates and that point at the stack, assuming that these pressures were taken at the same levels.

The theoretical draft or pressure head on Kiln 2 measured on a gage at the base of the stack 53 feet high, if the ashpit opening and all other openings in the kiln were closed and the mean temperature in the stack were 1500°F, would be equal to

$$53 \times 0.192 \times 0.0807 \left[\frac{460 + 32}{460 + 75} - \frac{460 + 32}{460 + 1500} \right] = 0.546.$$

If the ashpit were opened and the gases allowed to flow the reading of the draft gage at the base of the stack would be less than 0.546 because a part of the total pressure head would be used to give the gases velocity and maintain that velocity against the frictional resistance of the stack.

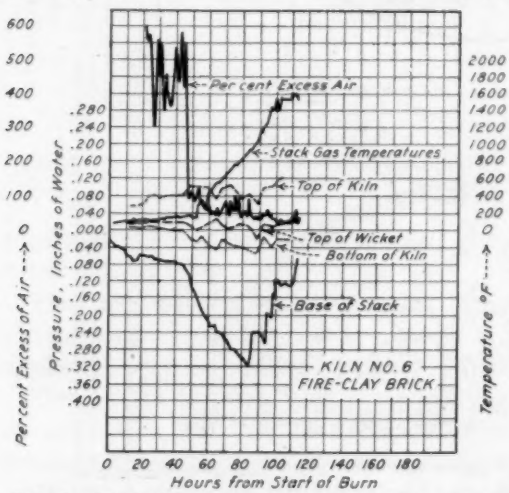

FIG. 5.—Variations in pressures at various points during burn.

At this time in this kiln the pressure read at the base of the stack was 0.360 inch and in the ashpit 0.008 inch of water less than atmospheric. Correcting for the difference of 9 feet in the two levels the true pressure drop between the two points is found to be 0.224 inch of water. If we had two kilns having exactly the same resistance or if in one kiln the resistance were constant then the depression in the stack would be a measure of the rate of flow of gases in the two kilns or at different times on one kiln, as the pressure drop varies as some power, about the square, of the velocity, or, pressure

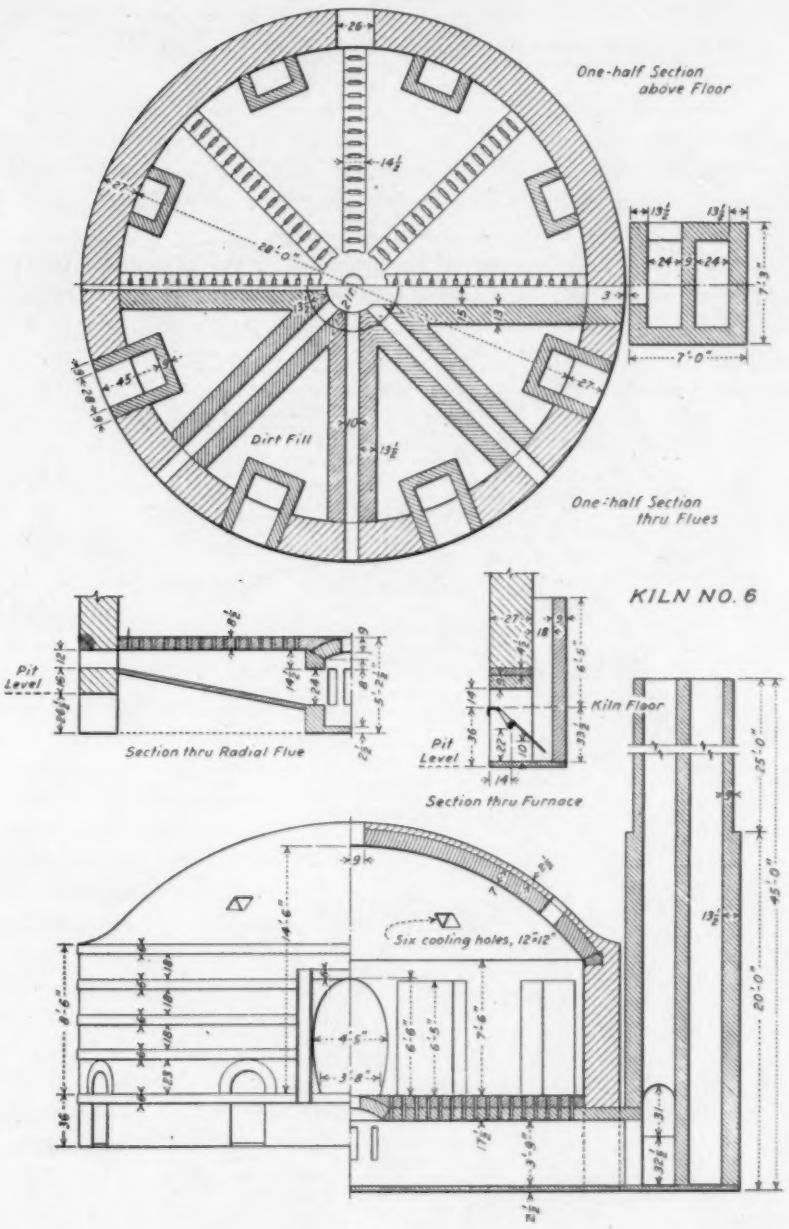
One-half Section above Floor
Dirt Fill
One-half Section thru Flues
KILN NO. 6
Pit Level
Section thru Radial Flue
Kiln Floor
Pit Level
Section thru Furnace
Six cooling holes, 12"x12"

FIG. 5a.

drop $= K \times V^n$ where n is probably approximately 2. The constant K depends on the size and shape of the duct, the roughness of the walls, and on the density and viscosity of the gas which in turn are dependent on the temperature.

The resistance at a given velocity from the ashpit to the base of the stack is a sum of the resistance of the fuel bed which is a variable quantity, and the resistance of the walls, ware, and flues which are practically constant quantities though the resistance of flues may change owing to change in cross-section by accumulation of dust and ashes.

If, therefore, a true reading of the pressure in the bottom of the kiln could be obtained together with the temperature of the gases the pressure drop through the flues could be used as a measure of the rate of flow of the gases through the kiln.

At the time that the temperature of the stack gases was 1500°F in the kiln considered above, the pressure reading obtained in the flue to the stack was 0.360 inch, that in the bottom of the kiln was 0.040 inch and in the ashpit was 0.008 inch of water less than the air at the corresponding levels. Correcting these readings for the difference in the levels the pressure drop from the ashpit to the stack or the total drop through the kiln was 0.224 inch of water and the drop from the bottom of the kiln to the stack was 0.213 inch of water. Therefore, at this time about 95% of the total pressure drop through the kiln occurred in the flue system. Since the resistance of the fuel bed varies from time to time this percentage will vary.

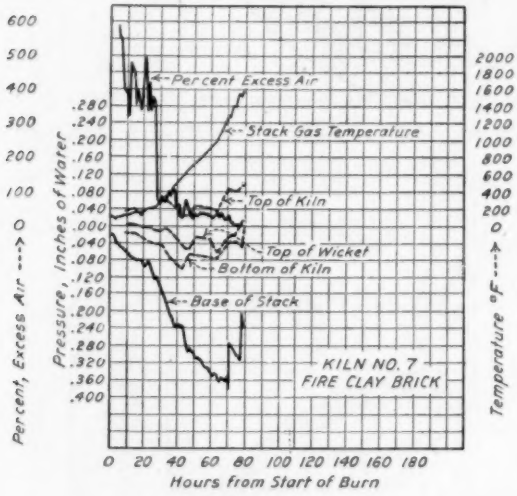

FIG. 6.—Variations in pressures at various points during burn.

A similar calculation at the time of maximum total drop for the other kilns shows that the pressure drop through the flues was approximately 65% of the total drop in Kiln 5, 80% for Kiln 6, and 74% for kiln 7.

The flue system, therefore, actually acts as a damper and it is evident that if the resistance of the flues were decreased the height of the stack could be decreased.

Actual Draft Required

Let us assume the gases in the kiln as moving through a duct as shown in Fig. 7 in the form of an inverted U in the direction *A* to *D*. When the grate is at the ground level the air pressures on the outside at each opening

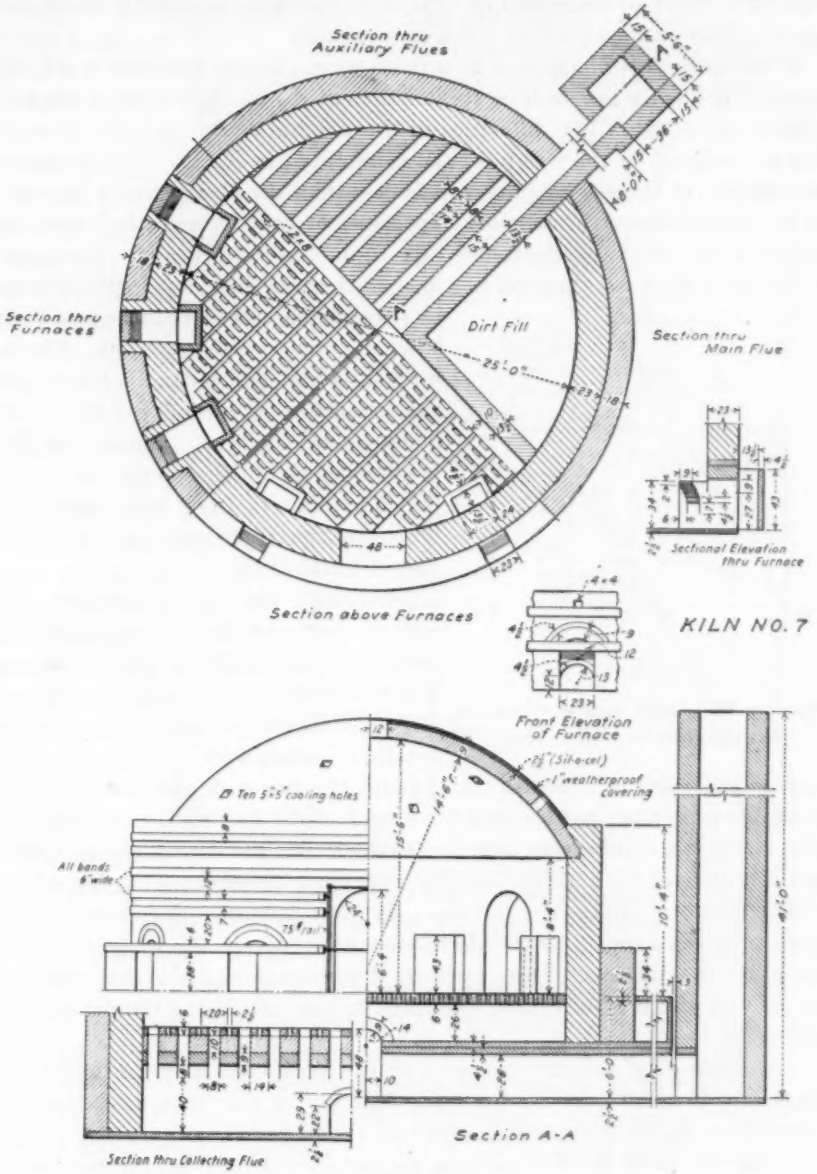

FIG. 6a.

of the duct are equal. Therefore, as the gases are cooler in the column CD than in AB, having given up heat to the ware, the weight of the column CD is greater than AB and the gases will flow out at D. If this difference is insufficient to draw the gases through at the desired rate, then the pressure at D must be decreased or that at A increased in order to move the gases. This may be done by a fan or by a stack.

If the grate level is moved to a point at A_1, above the floor level the pressure of the air at D will be greater than at A_1, by the weight of the column of air A, A_1. The difference in the weights of the two gas columns will be changed by the weight of the column of gas A, A_1. The change in the weights of the gas columns will be less than the change in the pressure of the air and hence the decrease in pressure at D or increase at A must be greater than before in order to move gas in the direction A to D. Similarly, if the grate level were moved to a point below the floor level the decrease at D or increase at A need be less than when at or above the floor level. Therefore, the resistance of the fuel bed and the walls being constant, the less is the distance of the grate above, or the greater below, the floor level the less is the depression or draft required at the bottom of the kiln in order to remove the gases from the kiln.

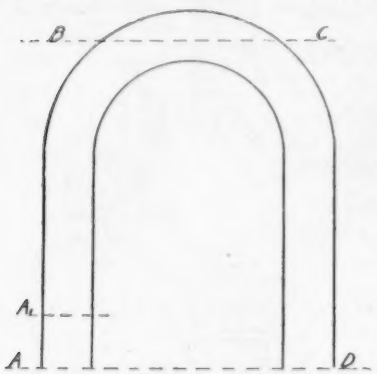

FIG. 7.—Imaginary duct representing path of gases through a kiln.

Obviously, the total pressure difference between the two columns depends on the height of the columns. The true height of the ascending column AB is difficult to determine. It is totally enclosed only by the bag-wall but as the ware is generally set around the bag-wall the true height is probably somewhat greater than the height of the bag-wall. It is possible that the pressure difference may be increased and the depression necessary at the bottom of the kiln decreased by increasing the height of the bag-wall.

The pressure difference between the two columns decreases as the burn progresses owing to the decreasing difference in the temperature of the gas in the columns. Thus, a greater depression is required at the bottom of the kiln which is, of course, produced by the increasing temperature of the stack gases.

The depression actually required at the bottom of a down-draft kiln, therefore, is small and the principal function of the high stack used on these kilns was to overcome the friction of the flues.

It has not been determined how the pressure drop from the bottom of the kiln to the stack is divided between the floor openings and the under-

ground flues. The openings in the floor must be small and their resistance, therefore, fairly high in order to secure a uniform distribution of the gases over the floor. If the resistance of these small openings constitutes the greater part of the total resistance, the resistance cannot be greatly changed by change in the design of the floor opening and flues.

It has been seen from the charts of the pressure conditions in various parts of the kiln that the pressure near the top of the kilns was greater than atmospheric and that in Kiln 6 the pressure was greater than atmospheric in the bottom of the kiln during the first part of the burn. In this kiln, it is to be noted that the grate level was below the floor level of the kiln.

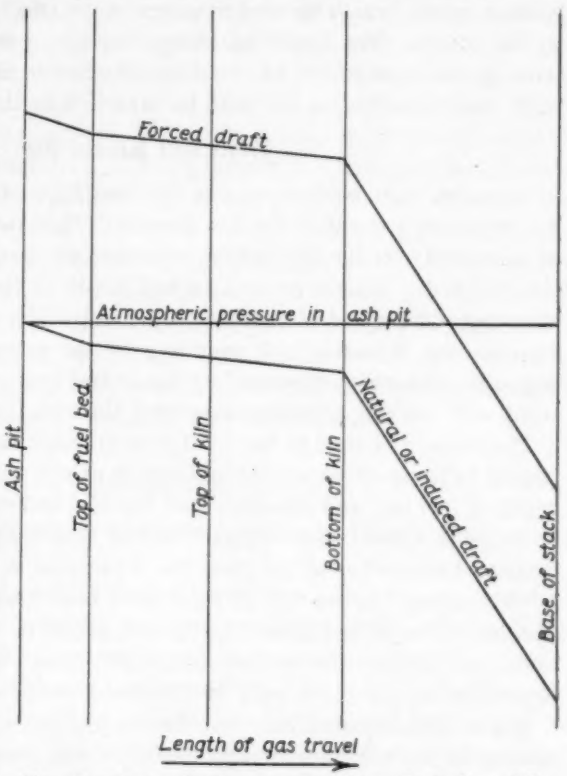

FIG. 8.—Approximate pressure drop through a kiln, using forced, natural or induced draft. assuming same resistance of fuel bed and kiln.

When the pressure inside the kiln is less than that outside, cold air will flow into the kiln through all openings, lowering the temperature of the gases and the ware. This is not especially harmful during the water smoking period but is detrimental later in the burn. Also, of course, when the pressure in the kiln is greater than that of the atmosphere, gases will escape from the kiln which may occasion a considerable loss of heat.

Therefore, the pressure within all parts of the kiln should be maintained as closely as possible at atmospheric pressure. Obviously, if the stack is dampered to reduce the depression the net force acting on the grate is decreased in the kiln and less coal may be burned. However, the temperature of the gases will be higher owing to the lessened infiltration of air and the temperature of the ware may often be raised faster with a dampered than with an undampered stack.

It has been pointed out that placing the grate level at, or below the floor level and increasing the height of the bag-wall will aid in maintaining the pressure in the kiln greater than atmospheric without decreasing the pressure head available to force air through the fuel bed.

When a kiln is lighted with a cold stack the available pressure head is very small. During the water smoking period it is desirable to force through the setting a large volume of gas at a moderate temperature. Several methods may be used to augment the small pressure head produced by the stack. The kiln may be operated as a semi-up-draft kiln by removing the covers from the cooling openings in the crown; a fire may be built in the stack or a fan may be attached to the stack.

Draft and Excess Air

Assuming that no free oxygen can pass through the fuel beds of a kiln the excess air present in the flue gases will vary directly as the ratio of the air admitted over the fuel bed, or secondary air, to the gases coming through the fuel bed. With a given area and depth of fuel bed and a given area of openings for air admission over the fuel bed the ratio of the pressure drop through the secondary air openings to the pressure drop through fuel bed and hence ratio of secondary air to fuel bed gases should remain constant with varying total pressure drop through the entire kiln.

Therefore, a change in the total drop through the kiln or the stack draft should have no effect on the amount of excess air in the flue gases, if the depth of fuel bed and openings over the fuel bed remain the same. It will be noted in Kilns 6 and 7 (Figs. 5 and 6) that the percentage of excess air decreased somewhat at the time the depression in the stack was decreased by dampering the stack. It may have been that at this time the firing openings were closed more tightly but assuming that they remained the same, the decrease in the percentage of excess air with a decrease in the depression in the stack may be explained as follows:

It has been pointed out that decreasing the stack draft increased the portion of the kiln in which the pressure was greater than that of the air outside. Therefore, some of the openings for secondary air admission were actually cut off and thus the ratio of secondary air to the fuel bed gases, and hence the percentage of excess air was actually decreased.

Forced and Induced Draft

It was pointed out in the introduction that the pressure difference necessary to move the gases through the kiln may be established in three ways: by forced, by induced, or by natural draft.

There is no essential difference in the movement of the gases by these three methods. That is, in order to move a given weight of gases through a kiln of given resistance the pressure drop through the kiln or through any

part of the kiln must be the same regardless of the method used to secure the pressure drop.

Furthermore, aside from eddy currents which, at the low pressure differences considered, are probably negligible, the distribution of the gases will be the same with the three methods. Forced draft will not force gases into corners, nor will induced draft "pull" gases out of corners when used under the same conditions as natural draft.

Fig. 8 shows graphically the approximate pressure drop through a kiln with the three methods, the resistance of the kiln and the weight of gases moved being the same. Pressures at all points are with reference to the pressure of the atmosphere at the ashpit. As natural draft is but induced draft by natural means instead of by a fan the curves for induced and natural draft are identical. The pressure in the ashpit with forced draft is greater than atmospheric and as the pressure drop through the kiln is the same as for natural draft the curve lies above and parallel to the curve for natural draft at all points. Consequently a greater portion of the kiln will be at a pressure greater than the atmosphere and the detrimental infiltration of air will be less with forced than with natural or induced draft.

An obvious advantage of mechanical draft, either forced or induced, is the possibility of securing a greater pressure drop and thus moving a greater weight of gases than might be possible with natural draft.

Conclusions

The pressure readings taken at various points in these round, down-draft kilns showed:

1. That readings taken at different levels in a kiln must be corrected for the difference in the pressure of the atmosphere at these levels if the true resistance to the flow of gases through the system is desired.

2. The depression or draft in the base of the stack is not a true measure of the pressure available to force air through the fuel bed but is only an indication of the resistance of the kiln and flues. The pressure drop from the bottom of the kiln to the base of the stack, which measures the resistance of the flues was from 65 to 95% of the total pressure drop through the kiln in the four kilns studied. It is apparent that a design of a flue system having a lower resistance would be desirable, particularly during the water smoking period, when it is desired to force through the setting a large volume of gases at a moderate temperature at which time the depression produced by the stack is small. If the low resistance flue system permitted too great a depression at a later stage of the burn the stack could be dampered. This is dependent on, at present, the undetermined resistance of the floor openings.

3. It is desirable to maintain as great a portion of the kiln as possible

at a pressure slightly greater than atmospheric to prevent the infiltration of cold air. This condition is favored by placing the grate level at or below the floor level of the kiln, and also, perhaps, by increasing the height of the bag-wall.

4. There is no essential difference in the movement of gases by forced, induced, or natural draft. However, with forced draft a greater portion of the kiln may be maintained at a pressure greater than atmospheric.

Acknowledgments

NOTE: Acknowledgment is made of the helpful criticisms and suggestions o John Blizard, Research Engineer, Power Specialty Co., S. M. Kier, Kier Fire Brick Co., and M. D. Hersey, Physicist, Bureau of Mines. The data were taken by the crew of the laboratory car "Holmes," A. W. Whitford, A. H. Fessler, Franklin Wentzel, Jr., E. M. Rupp and W. T. Askin.

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DEVITRIFICATION IN A LIME-FLINT GLASS TANK[1]

By A. R. Payne

ABSTRACT

A brief account of the formation of cristobalite in a tank of soda-lime glass due to failure of the refractories in the bridge-wall. The efforts made to eliminate this devitrified glass are described. These efforts were not successful and the only solution was to shut the tank down and rebuild it.

The tank in which the devitrification occured has a melting end forty feet by twenty feet. Its refining end is twenty-two by twenty-eight feet and is roughly semicircular. Grouped about the refining end of the tank are eight presses, fed by flowspouts. The glass in the tank is forty-two inches deep. The bridge in the tank at that time was of the regular type being pierced by two holes for the flow of the glass and having a longitudinal passage for the air and water cooling system.

The glass being made was of the lime-flint type. An average analysis would be

SiO_2.....	73.23%
R_2O_3.....	0.56
CaO.....	4.54
MgO.....	3.43
Na_2O.....	18.24

The tank was started April 1, 1923. For four months the glass was normal. The average temperature in the melting end of the tank was about 2550°F, and in the refining end it was 2200–2250°.

About August 5, we began to get "dirty glass" from several of the flowspouts. This was intermittent and the scum was in small lumps. It was accompanied by cords. Invariably the "scum" crystals were in the cord. From that time on the glass was cordy on two or three shops continually.

The scum was not visible in the melting end of the tank. No batch piles ever got beyond the second port. Beyond that port the surface of the glass was as clean as a mirror.

When viewed through the flowspouts there was scarcely any scum visible in the refining end. It collected in the flowspouts, and adhered to the sides of the spout and to the plug. At times this scum was skimmed off the top of the glass in the flowspout and as a consequence there was less for several hours.

This dirty glass and cord occurred on certain shops only. The two corner shops always had good glass. The flowspouts where this scum emerged were not "cold." We tried heating them until the glass ran out like water with no benefit resulting. The glass then coming out was

[1] Presented at the Atlantic City Meeting, Feb., 1924. (Glass Division.)

much too hot to be pressed, yet it was still cordy and contained this scum.

At no time during this devitrification trouble was the glass seedy

We knew that the scum was not forming in the flowspout as the glass had been allowed to flow out extremely rapidly and the flowspout emptied itself in a very short time.

Composition of the Scum

The scum samples were analyzed and were found to run high in silica. We pronounced the crystals to be cristobalite or tridymite. Samples were sent to Dr. Insley of the Bureau of Standards and he confirmed our ideas and pronounced them to be cristobalite.

A typical analysis of this scum was:

SiO_2.....	76.21
R_2O_3.....	0.82
CaO.....	3.82
MgO.....	2.90
Na_2O.....	16.25

This appeared to be the regular glass with some extra silica. When samples of the glass from each shop were taken and a composite analysis was made the results indicated that the batch entering the tank was normal and that we were getting every pound of every constituent that we were supposed to be getting. In all we made seven analyses of the glass from this tank.

Use of Alumina

Knowing the advantages obtained by the presence of alumina we procured some aluminum hydrate and used 20 pounds per 1000 pounds sand for several days. This seemed to cut down the actual scum but did not improve the situation with respect to the cords.

Increase of Temperature

We increased the temperature of the refining end to 2350–2375°, and in the melting end to 2600°F with no real improvement being shown.

Change in Batch

With the idea that a stiffer glass might be less liable to crystallize in the danger zone (2200–1800°F), we decreased the quantity of soda ash in the batch. This change brought no betterment in the glass.

Conclusion

We were then of the opinion that we had exhausted our resources. It was decided that the crystallization was all occurring in the bridge and that batch changes and temperature changes were not sufficient to overcome the tendency of the glass to devitrify as it came in contact or near the water log in the bridge. We then had to choose between withdrawing

the water log or shutting the tank down. It was a case where we had to choose between a continual fight against a slowly disintegrating bridge and a shutdown for quick repairs. We decided to shut the tank down. It was found that the glass had eaten the blocks in the bridge until it had exposed the water pipe. The glass surrounding the water pipe was completely devitrified and it was the continual sloughing away and the renewal of this mass of crystals that had been the source of our troubles.

HAZEL-ATLAS GLASS CO.
CLARKSBURG, W. VA.

COMBATING LAMINATIONS AND IMPROVING THE BRICK STRUCTURE[1]

By Davis Brown

Laminations are understood to be a succession of layers forming the rectangular structure of a brick and that the bonds between these layers are the weak points in the brick.

The causes of these laminations are fairly well understood but the remedy is a different matter.

The cause comes from a difference in the rate of travel of the material at different points under pressure, while undergoing change in size and shape necessary to convert the mass of material from a round to a rectangular section and to a reduced area. In undergoing this change it is necessary for the component parts of the structure to rearrange themselves in their relation to each other so that when the material issues from the die the structure is more or less laminated and of different densities at different points of its cross-section.

It is naturally of increased density near the corners or angles and of a lesser density at the center of the column where there is practically no resistance to its outward flow. In general, fatty clays laminate badly, the shrinkage is high and there is a tendency for the layers to separate during the drying and burning stages, being generally more pronounced at the latter period. Lean clays are not so susceptible and laminations do less harm owing to the fact, I believe, that the shrinkage is less.

The harmful effects of laminations are minimized by reducing them in whatever way possible. The most effective way is by reducing the plasticity of the clay, by adding grog or other suitable materials.

As regards the auger machine, there is evidently a proper ratio between the area of expressing cylinder and the area of the die but the requirements of the clay worker are so varied that it is difficult for the manufacturer of clay working machinery to cover them all.

Some fifteen or more years ago, when designing a new line of auger machines, I provided each machine with three sizes of expressing augers with sectional interchangeable bushings so the user could maintain the proper relation between diameter of auger and size of the die, which went a long way toward accomplishing the object in view.

All kinds of dies have been made but the choice has been pretty well narrowed down to three varieties and one or another of them is almost certain to give satisfactory results under favorable conditions.

The die should be kept as close to the auger as the material will permit as it saves power and wear and tear and the clay is not subjected to so much pressure. For the same reason, I believe in using as short a die as

[1] Recd. Jan. 3, 1924. Presented at the Atlantic City Meeting, Feb., 1924. (Heavy Clay Products Division.)

the material will stand for as the more pressure required to force the clay through the die, the greater will be the difference in density between the center of the column and the outside.

At various times since about 1885, when I commenced to design clay working machinery, I, like many others, have had dreams of being able to overcome laminations, and have made many experiments with that end in view. In 1891, I built a roller machine in which a pair of rollers supplied pressure for forcing the clay through the die; installed one, as nearly as I recollect, at Stansberry, Mo., one at Cherokee, Iowa, one at Decatur, Ill., and one somewhere in Tennessee.

They all made a satisfactory brick with the exception of the one sent to Tennessee; the brick were somewhat laminated but in a different manner from those made on an auger machine and similar to those made on a plunger machine. The Tennessee machine was working a clay that was very fatty and when the customer sent a sample brick made on the machine it was apparent that the machine in question was not the solution of the difficulty and eventually all of them were replaced. What lead me astray was the fact that I did not procure a badly laminating clay for making the first trials.

The above experience cured me for a long time but of late years the dreams have recurred with so much persistency that I am at it again. This time the first trials were made with a clay which was giving serious trouble to the brick manufacturer. The brick would warp and check in the center and this difficulty was only minimized by mixing another clay, or grog, incurring much expense.

After working this clay successfully, I procured another of like characteristics and have succeeded in making samples of marketable brick from it.

At the present writing there are paving brick, fire brick and flux blocks made on this machine, undergoing physical tests and I am living in hope of being able to announce at an early date that the harmful effects of an imperfect brick structure need not be longer tolerated.

The plunger machine and the roller machine eliminate the "auger laminations" and retain "die laminations." The machine in question does not depend on an auger for creating the necessary pressure, nor a die for forming the column. It consists of three endless belts so arranged as to form a trough open at both ends and at the top. In this trough is a large roller located at the discharge end. The surfaces of all belts and the roller are driven at the same speed and in the same direction, where they are in contact with the clay. The space between belts forming the sides of the trough equals the length of a brick and the space between the roll and the belt which forms the bottom of the trough equals the width of the brick.

The prepared clay is fed into this trough behind the roll and issues in a

column in the same manner as from any other brick machine but the column of clay is of uniform density; the brick do not warp and there are no weak spots anywhere.

On first going over this machine it would appear that as the material and moving parts in contact with it, travel at the same rate of speed, that it would be impossible to form laminations in the column issuing from the machine. This is borne out in practice so long as the supply of material is limited to that required to form the column free from voids and no more, as when an excessive amount of material approaches the point of greatest compression the excess material will flow backwards away from the roller and some laminations will appear in the column.

This is taken care of by means of a device for limiting the supply of material to the right amount. This device consists of an adjustable roller at the bottom of the hopper which once adjusted to the proper position for the material being used, permits the right amount to pass to the compressing roller, so long as material is kept in the hopper.

The main cause of weakness in a brick structure does not come so much from the laminations themselves as from the unequal density of the material at different points of the structure. The less dense portions shrink more than the dense portions, setting up stresses within the structure and reducing the strength of the brick.

In some of my demonstrations when using a laminating clay I have caused laminations to form in the column when supplying an excess amount of material yet the brick dried and burned safely and were straight and sound.

It is my ambition to be of service to the clay working industry and it is hoped that the presentation of this material will be of service in opening up a new line of thought or will prove of assistance in bringing about substantial advancement to that industry.

THE HADFIELD-PENFIELD STEEL CO.
BUCYRUS, OHIO.

THE EFFECT OF FURNACE ATMOSPHERE ON THE FIRING OF ENAMEL[1]

By R. D. Cooke

ABSTRACT

It is shown that in firing ground coat and other one coat enamels, the atmosphere of the furnace plays an important part. Oxygen in the muffle penetrates the enamel during the early stages of the firing forming a film of iron oxide on the surface of the steel. This film, whether applied before enameling or formed incidentally to firing, partially dissolves in the fused enamel giving the intimate bond between metal and enamel.

Ground coat enamel fired in an atmosphere of nitrogen was found not to adhere to the steel.

Approximate values are given for the proportion of furnace space to enameled surface to insure sufficient oxidation when residual air is depended upon to supply the oxygen.

It is the purpose of this paper to record a few fragmentary data on the firing of enamels rather than to be a complete study of the subject. The problem was encountered incidental to other work and was followed up from time to time as one observation suggested and led up to another.

While experimenting with melting small quantities of powdered ground coat frit on pieces of bare sheet steel, it was noticed that under the pile of frit the steel oxidized from the heat with nearly the same readiness as on the bare surfaces. This led to further experiments to determine whether the surface of the steel always oxidized from the heat when the ware was fired. It was found that it did. Ground coat biscuit ware was placed in a furnace a few seconds and withdrawn before the enamel had sintered. The enamel was washed off with water and it was found that the surface of the steel had become oxidized or blued. This observation is quite familiar to enamelers, but it is doubtful whether the full importance of the fact is realized.

Effect of Oxidized Versus Non-oxidized Iron in the Enamel

A number of small melts were made to show the effect of admixtures of iron and iron oxide to the enamel. A sample of dried ground coat enamel containing all of the mill additions was mixed with 20% of its weight of powdered iron scale and another sample with the same quantity of iron filings. These were melted by heating for five minutes at 900°C in covered porcelain crucibles. When cold the crucibles were broken and the interior of the melts examined. The melt with iron oxide was clear and quite free from bubbles, while the one with metallic iron was very spongy. This was another indication that in the proper firing of ground coat enamel the oxidation of the steel was more than incidental to the process; it appeared to be a vital necessity.

[1] Presented at the Atlantic City Meeting, Feb., 1924. (Enamels Division.)

Equipment for Exact Studies

An electrically heated tube furnace (a laboratory carbon combustion furnace with silica tube) was so arranged that samples of bare or enameled steel could be introduced by resting them on a Monel metal boat, and pushing into the tube with a stiff wire. The opposite end of the tube was connected to a gas holder from which a current of any desired gas or mixture of gases could be maintained in the furnace.

Enameling Steel in Normal Atmosphere

Samples of clean steel were enameled with ground coat and fired in this furnace with a moderate current of air flowing. The enamel after firing was normal in every respect.

Enameling Steel in Atmosphere of Nitrogen

The atmosphere in the furnace was then changed to nitrogen and a number of pieces fired in the same way as before. The result was truly remarkable. The enamel had melted and rolled up into drops like water on a greasy surface, leaving areas of bright clean steel between. It adhered to the steel so poorly that most of the enamel could be rubbed off with the fingers.

Oxidizing the Steel before Enameling

Following this a number of pieces of clean steel were oxidized by heating for a few seconds at 750 °C and then enameled. These were fired in the atmosphere of nitrogen and came out as perfectly as those fired in air.

Summary of Evidence and Theory

Thus the fact was definitely established that the oxidation of the steel, by penetration of air through the porous enamel during firing, is a vital step in successful enameling. The true function of this oxide is not known, but a plausible hypothesis is that the film of oxide is dissolved in the enamel, at the higher temperature, forming a transition layer of composition varying from 100% enamel on the outside to 100% iron oxide next to the steel. The nitrogen experiment would seem to indicate that clean steel is not wet by fused enamel, while the enamel does wet iron oxide.

Reactions Involved in Firing Enamels

Equipment Used

The tube furnace was finally arranged to enable a more complete study to be made of the reactions involved in firing enamel. The silica tube extended several inches beyond the furnace at each end. At one end were connected a thermocouple extended into the heated zone, a manometer for observing the pressure in the tube, and a connection for gas or air supply. At the other end was an outlet for gases and device for pushing an enameled sample from the cold to the hot part of the tube, working through a stuffing box in order that the tube might be kept air tight while the

sample was being fired and withdrawn. If desired the sample could be allowed to cool in the end of the tube before breaking the seals and removing it.

Samples

The samples used were strips of steel three inches long and three-quarters of an inch wide bent lengthwise to a V-shape. The two edges rested on a Monel metal carrier. These samples were pickled and enameled in the regular way.

It was found that all pieces blistered badly when the air standing in the tube was depended upon to supply the oxygen. For normal results it was necessary to draw a slow current of air through the tube while the sample was being fired. About 100 cc. per minute was ample.

Effect of Pressure

With these conditions as standard, samples were fired under reduced pressures by partially closing the air inlet. There was no bad effect from reducing the pressure to five inches below the barometer. This made it clear that variations in the barometric pressure could not effect the firing. All further experiments were made at atmospheric pressure.

Effect of Neutral and Slightly Oxidizing Atmospheres

In an atmosphere of nitrogen the enamel blistered badly and collected in drops as before. In an atmosphere of carbon dioxide the enamel blistered but not as badly as in nitrogen. Pieces of bare steel heated in carbon dioxide oxidized slightly from reduction of the carbon dioxide to carbon monoxide, but the oxidation was not enough entirely to prevent the enamel from blistering.

Amount of Oxygen Required

An effort was made to determine the quantity of oxygen taken up by the sample by analyzing the exhaust air from the tube. To avoid an unnecessary excess of air it was first necessary to determine the minimum rate of flow which would give good results. This was found to be 100 cc. per minute. When the rate was reduced to 90 cc. per minute the enamel blistered and spalled. To overcome the diluting effect of the large air spaces at the ends of the tube outside of the heated zone, the incoming air was carried through a capillary porcelain tube up to within an inch of the sample. The air was drawn out at the other end in the same way, the small porcelain tube being used to push the sample carrier into the furnace.

The average analysis of five samples of air collected in this way was: Carbon dioxide 0.7%, oxygen 16.5%. Since the original oxygen content of the air was 20.6% the amount absorbed was 4.1% of the total air passed. The rate of flow was 100 cc. per minute, and the sample was in the furnace one minute, therefore, the amount of oxygen absorbed was 4.1 cc. measured at room temperature. The total area of the sample was six square inches.

When Is Oxidation Effective?

The oxygen was probably not being taken up throughout the firing period. This was shown to be true. A number of samples were fired with the air passing at the rate of 200 cc. per minute, and the samples left in the furnace exactly one minute. The air supply was cut off during different parts of the minute and the effect noted.

When the air was flowing the first thirty seconds and not during the last, the enamel was good. Under the reverse conditions, air flowing only during the last half minute, the enamel blistered.

When air was flowing only during the first quarter minute the enamel was bad, but when flowing only during the second quarter minute it was good.

The absorption period was narrowed down to the five-second interval between 15 and 20 seconds. For good results it was necessary that the air be flowing during that interval, which was presumably the interval just before the porous enamel fused to a continuous film.

If the 4.1% of oxygen absorbed were all taken up during that five seconds it is clear that for a moment the air surrounding the sample must have been entirely deprived of its oxygen.

Relation of Furnace Space to Area of Enameling Surface

In the practical firing of ware there is ordinarily no attempt at circulation of air in the muffle. The required oxygen must be found in the air standing in the furnace. The experiments thus far described failed to give any data which could be interpreted in terms of volume of furnace space required per square inch of enamel surface. The expedient was then tried of reducing the size of the samples fired in a fixed furnace space until the results were good. Strips of steel four inches long and $^3/_4$, $^1/_2$, $^1/_4$ and $^1/_8$ inch wide were enameled and fired in the tube furnace with no air flowing, but introducing fresh air into the furnace after each firing. It was found that the blistering or ruffling of the surface decreased with each decrease in the size of the sample until the $^1/_8$-inch strips were good. If it is assumed that the active furnace space extended one-half inch beyond the ends of the sample, the volume of the space was three cubic inches. The smallest sample had a surface area of one square inch. Since even this sample was not quite perfect it is safe to add at least 100% as a safety factor.

The conclusion is, therefore, that under the conditions of these experiments there should be for satisfactory firing six cubic inches of furnace space for each square inch of enamel surface.

It is admittedly taking a great deal for granted to assume that this conclusion can be applied to practical furnace conditions, mainly because there is nothing to show that air one foot from the enamel surface is as available as that within one inch. However, it is not without interest to

compare this ratio with that found in practice in a number of typical instances. A number of items were chosen which off-hand appeared to have the greatest surface per furnace load. The surface areas were calculated from the weight of the ware and the known weight per square foot of the sheet steel. Two sizes each of coffee pots, tea kettles and milk kettles were figured. It was found that the cubic inches of furnace space per square inch of enamel surface varied from 9.8 to 14.1. The ratio of six to one is more likely low than high, and when it is seen that in practice the ratio may be as low as ten to one, it is obvious that the limit of safety may sometimes be passed.

The blistering mentioned in these paragraphs should be described as a very fine blister, appearing superficially as a mere dulling of the surface like very fine sandpaper. It was further observed that when the samples were drawn from the furnace and while still hot the surface was smooth and glossy. The blistering or ruffling occurred during cooling, and resembled somewhat the ruffling of the surface of molten paraffin wax when it solidifies. This effect was never seen when there was sufficient air in the furnace.

The experiments described above were performed on a ground coat enamel. All of them, however, were repeated on a one-coat gray enamel with identical results.

COLUMBIAN ENAMELING AND STAMPING CO.
TERRA HAUTE, IND.

OBSERVATIONS ON THE PROPERTIES OF CLAYS AND CLAY-GROG BODIES

By Edward Schramm

ABSTRACT

Determinations of shrinkage, absorption, and transverse strength were made on a series of clays and clay-grog bodies fired together. Highly porous grog bodies are obtained with tight burning clays when the latter possess high shrinkage. This is due to the formation of crevices between the clay and grog particles, and to produce a tight grog body the clay must be of low shrinkage and low porosity.

The data recorded below were obtained incidental to an investigation of sagger mixes and they are presented as a small contribution toward that much debated problem. The properties of a sagger mix or of any clay-grog body are determined by the nature of the clay, by the nature and grading of the grog, and by the kind of structure produced when the mixture of clay and grog is fired. To throw some light on the third factor, the interaction of clay and grog, the usual physical properties were determined for a number of clays and clay mixes and for the corresponding grog bodies with 50% of flint-clay grog. Two gradings of grog were used of the following analyses:

		A	B
Per cent rejection on	8-mesh	0	0
	14	1.7	31.7
	28	25.7	40.3
	48	33.0	19.8
	65	17.2	3.2
	100	3.0	1.7
Through	100	19.4	3.3
		100.0	100.0

The data on grog A briquettes is given in Table I, on grog B in Table II.

The tests recorded in Table I are of earlier date than those in II, and in the former case the strength of the fired clay was not determined. The briquettes were made by pressing in plaster molds. The clay was prepared by blunging into a slip, drying on plaster bats and careful wedging. In the case of grog mixes the grog was spread over the wet clay on the bat and thoroughly mixed in by wedging. All briquettes were first air dried and finished in an oven at 110°C. They were fired in the biscuit kiln bedded in kaolin. The measurements given are the average of four.

The figures, while not altogether consistent, enable us to trace certain general relationships between the properties of the clays and the clay-grog bodies made from them. The shrinkage of the grog mix is of course roughly proportional to that of the clay. With respect to absorption the relationship is not so simple. One might expect that the tighter burn-

ing clays would give a tighter grog body but this rule does not always hold. Thus in Table I we have two ball clays designated as Tennessee and Western and clay mix G which are vitrified or nearly so when fired alone and which yet give grog bodies of the highest porosity. On the other

TABLE I

FIRED CONE 10

	Clay Briquettes			Grog Briquettes					
Clay	Per cent shrinkage Drying	Total	Per cent absorp.	Per cent shrinkage Drying	Total	Per cent absorp.	Mod. rupt., lbs./sq. in.	Theoretical absorp.	Actual minus theoretical absorp.
Ky. Ball	4.25	12.25	0	3.9	7.0	11.8	2397	4.5	7.3
Crucible	5.00	10.75	0	3.2	6.0	9.6	2447	4.5	5.1
Tenn. Ball	4.75	14.50	0	4.0	8.5	15.3	2048	4.5	10.8
Mix B	3.75	12.00	7.2	3.2	6.2	13.4	2117	8.1	5.3
Mix A	5.00	12.12	4.1	3.2	6.3	12.4	2290	6.5	5.9
Mix D	4.37	11.25	1.8	3.8	7.0	12.5	2400	5.4	7.1
Mix E	5.62	11.25	0.8	4.0	7.0	12.7	2237	4.9	7.8
Mix G	3.75	14.37	1.3	4.0	9.0	14.4	2347	5.1	9.3
Mix I	3.75	11.25	3.0	3.0	6.8	12.8	2510	6.0	6.8
Mix J	4.00	11.25	6.3	3.5	6.2	12.7	2363	7.6	5.1
Western Ball	5.30	16.00	2.0	5.2	9.4	16.3	2200	5.5	10.8
Western Sagger	4.50	13.00	6.1	4.3	7.9	13.1	2627	7.5	5.6

hand, in the same table we have the crucible clay of zero porosity giving the lowest porosity of any of the series of grog bodies. It will be noted, however, that the vitrified clays giving grog bodies of high porosity are characterized by high shrinkage while the crucible clay has a low shrink-

TABLE II

FIRED CONE 11 HALF OVER

	Clay Briquettes				Grog Briquettes					
Clay	Per cent shrinkage Drying	Total	Per cent absorp.	Mod. rupt., lbs./ sq. in.	Per cent shrinkage Drying	Total	Per cent absorp.	Mod. rupt., lbs./ sq. in.	Theoretical absorp.	Actual minus theoretical absorp.
Eng. China	4.0	10.1	20.8	3709	1.0	5.5	17.4	820	14.9	2.5
Fla. Kaolin	7.0	16.6	13.8	6420	3.6	8.1	16.3	1040	11.4	4.9
Tenn. Ball	6.0	14.6	0	6967	3.0	9.2	10.8	1572	4.5	6.3
Ky. Ball	6.0	14.0	5.4	5860	3.2	8.1	11.0	1780	7.2	3.8
Crucible	7.0	12.5	0.7	9937	3.0	7.2	9.1	1613	5.2	3.9
Ground Shale A	4.5	7.0	6.8	3366	2.0	5.5	9.4	1369	7.9	1.5
Ground Shale B	5.0	10.2	3.4	3341	2.0	6.0	9.4	1667	6.2	3.2
N. J. Fireclay	5.0	14.0	12.9	....	3.0	8.2	15.0	1415	11.0	4.0
Eng. Ball	6.0	14.8	0	6580	4.0	8.9	9.9	995	4.5	5.4

age. It is evident that the shrinkage of the clay may be a factor of greater moment than its tightness in determining the porosity of a grog body.

In the series given in Table II we used a somewhat coarser grog and a greater variety of clays. At first glance the results do not appear so clear-cut but again we note that the Tennessee, Kentucky, and English ball clays of high shrinkage produce a more open grog body than the crucible clay or ground shales although the latter are more open in the clay state. On the other hand, when we are dealing with the very open burning clay such as the English china clay, Florida kaolin or New Jersey fire clay, it is apparent that the high porosity is due in part at least to the characteristics of the clay itself.

We may regard the porosity of a grog body as the sum of three components: (1) the porosity of the clay; (2) the porosity of the grog; (3) the pores and crevices which develop between clay and grog particles. We may calculate the porosity due to the first two factors from the known porosities of the clay and grog (9% absorption for flint clay). These values are entered in the table as theoretical absorption. The difference between the actual absorption and this theoretical absorption gives an idea of the extent of formation of crevices. It is the porosity due to these crevices which increases with increasing shrinkage of the clay and accounts for the highly porous bodies which may be obtained with vitrifying clays. The ideal clay for the production of a tight grog body is one which possesses both low shrinkage and low porosity.

The figures for modulus of rupture illustrate the well-known fact that the strength increases with decreasing size of grog. It is difficult to find any consistent relationship between the strength of the clay and clay-grog briquettes though it may be noted that the two ground shales exhibit the least falling off in strength when made into grog bodies. The bodies made from these clays also exhibit the smallest number of large crevices and the smallest differences between the actual and theoretical absorptions. The strength of a grog body is affected by the strength of the clay and of the grog, by the force of adhesion of clay to grog, by the number and distribution of cracks. The factors are so numerous as to make analysis impossible with any existing data.

ONONDAGA POTTERY CO., LABORATORY
SYRACUSE, N. Y.

ONE FIRE WHITEWARE AND ART WARE THROUGH DIRECT FIRED CAR TUNNEL KILN[1]

By A. E. Hull, Jr.

Introduction

The Harrop Car Tunnel Kiln recently installed at plant No. 2 of the A. E. Hull Pottery Co., Crooksville, Ohio, is most unique and interesting. This kiln was placed in operation in August, 1923, and is firing art ware, cooking ware, stoneware and whiteware with but a single firing. Each car setting is composed of these different kinds of ware—there being no distinction as to the location of the different kinds on the car. Practically a uniform burn is obtained over the entire setting. Ware is also fired open on top of the sagger bungs.

Size

The kiln is constructed with a side entrance vestibule at both the charging and discharging ends. The length from outside of vestibule to outside of vestibule is 307 feet. It accommodates 46 cars, 6 feet 7 inches long. The placing width is 4 feet 10 inches wide and the placing height 4 feet 10 inches.

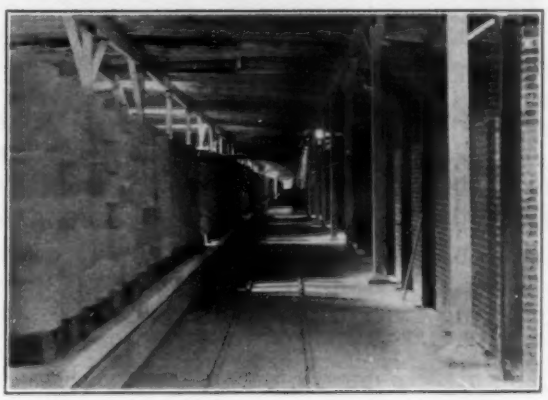

Fig. 1.

Capacity

The car setting contains an average of 435 pieces of ware.

The kiln delivers 31 cars of fired ware every 24 hours or 217 cars per week.

This gives an average production of 94,395 pieces of fired art ware, cooking ware, stoneware and whiteware per week, which is equivalent to the drawing of approximately five and one-half 30-foot diameter periodic kilns per week.

Time Schedule

Operating at a capacity of 31 cars per day requires the charging and discharging of a car every 46 minutes. This schedule requires but 35½ hours for a car to travel entirely through the kiln. Sixteen and one-half hours are required to pass through the heating-up zone and three

[1] Presented at the Atlantic City Meeting, Feb., 1924. (Whitewares Division.)

hours for the fire zone. This is a very large decrease in total firing time as compared to former periodic kiln practice in this plant. Although operating at a fast time schedule, the temperature at the charging end of the kiln is but 180°F and the temperature at the discharging end is only 170°F.

There are four furnaces on each side of the kiln, although only three on each side are being fired. Highly oxidizing conditions are maintained throughout the kiln at all times.

FIG. 2.

Operation of the Kiln

Due to the design and layout of the kiln, the operation is ideal. One man on each shift fires the kiln, maintaining the temperature, attending to the charging of the cars and taking the fired cars from the discharging end.

After a kiln car is pushed on the charging end transfer car, which in turn is placed in the charging end vestibule, an oil hydraulic car ram pushes the kiln car from the transfer car, moving the entire train of cars

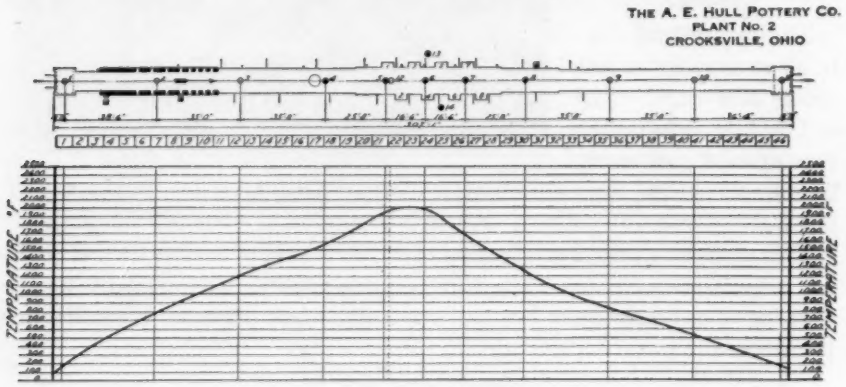

FIG. 3.—Temperature record, Harrop car tunnel kiln No. 1.

through the kiln at the rate of 1.7 inches per minute. The forward movement of the train delivers one kiln car onto the transfer car in the discharging end vestibule for every car introduced at the charging end. When the kiln car is entirely on this transfer car, both are removed from the

vestibule and the kiln car is placed on the return track. This latter track is completely filled with kiln cars, which are moved by a second hydraulic ram at the same rate as the train of cars in the kiln. This movement, being slow, is not objectionable to the kilnmen in placing and drawing the ware. It is so much easier to place and draw ware on a tunnel kiln car, where the sagger bungs are not high, that the kilnmen, without exception, say that they never want to work in periodic kilns again.

It is interesting to note that the total force required to move the train of cars in the kiln is 8300 pounds, while the force required to move the train of cars on the return track is 8000 pounds, there being but 300 pounds difference.

The kiln is equipped with Maxon Premix gas burners which are controlled by needle valves, thus requiring but little attention for regulation.

Advantages

The installation of this kiln has done a great many things for the A. E. Hull Pottery Co. We are obtaining a more uniformly fired product with a larger percentage of number one ware. In operating, placing and drawing, there is a labor saving of about 40% over our former periodic kiln practice, and there is also a fuel saving of about 85% over our periodic kiln practice. Due to the fact that the firing time is faster than in the periodic kilns and it being possible to single-fire the ware, production is speeded up considerably.

Last but not least, only about one-third of the number of saggers used in the periodic kilns are necessary with the tunnel kiln to obtain the same production. Furthermore, the actual saving in sagger breakage is approximately 25%.

A. E. Hull Pottery Co.
Crooksville, Ohio

THE ELECTRIC BRASS FURNACE REFRACTORY SITUATION[1]

By H. W. Gillett[2] and E. L. Mack[3]

ABSTRACT

The three prominent types of electric brass furnaces are described, and the conditions which they impose on the refractories are outlined. The limitations which the properties of refractories place on the applicability of the various furnaces are considered and an attempt made to point out lines along which development and improvement are most likely to take place.

Introduction

The makers of electric brass furnaces admit that there is a refractory problem in the application of induction furnaces to alloys high in copper. Outside of that, each maker seems to feel that while the other furnaces have their unsolved refractory problems, he has his own well in hand.

Such service reports as the refractory maker gets are usually of conflicting natures, although reports of short refractory lives seldom fail to reach him promptly. Consequently the situation does not seem entirely clear to him, but, on the whole, he is inclined to believe that his materials give reasonably good service.

The furnace user thinks of the problem in terms of dollars and cents per ton of metal melted and, while he generally finds his over-all costs are very satisfactory with the electric furnace in comparison with fuel-fired furnaces, yet would like to whittle down his costs a little more by getting longer service from his linings before replacement. The user sees the problem as a rather larger one than any of the other interested parties, and is often at a loss to know whether he is using the best lining for his job or getting as good results from it as he should expect. He generally gets some guidance from the furnace maker who is in touch with many installations but is not always inclined to accept the furnace maker's view-point as entirely unbiased. The user will probably welcome an airing of the subject—the refractory maker and furnace maker may or may not.

The least satisfactory spot in the situation is the induction furnace for high copper alloys, but the other furnaces have problems almost as interesting.

One of the writers discussed the "Metallurgical Requirement of Refractories for Furnaces Melting Copper Alloys" in a paper before the American Ceramic Society last year,[4] but it will be necessary to go over again some of the ground covered in that paper in order to make the present situation clear.

Types of Furnaces

There are three main types of electric brass furnaces: the granular resistor (Baily), the moving indirect arc (Detroit and Booth) and the in-

[1] Published by permission of the Director of the U. S. Bureau of Mines. Presented at the Atlantic City Meeting. (Refractories Division.)

[2] Chief Alloy Chemist, Ithaca, N. Y.

[3] Assistant Alloy Chemist.

[4] H. W. Gillett, *Jour. Amer. Ceram. Soc.*, **6** [4], 596(1923).

duction (Ajax and G. E.). Each has some refractory problems common to all types, but each also has some special problems of its own, and it is simpler to take each type up separately.

Granular Resistor

The Baily furnace, Figs. 1 and 2,[1] operates with a granular carbon resistor in a carborundum trough as the source of heat. Granular resistors are prone to develop hot spots, and it is necessary to run the resistor at such a high temperature that carborundum is the only available refractory that will stand up, and there actually is but a very small margin between the necessary resistor temperature and the decomposition point of carborundum. The trough is the weakest part of the furnace and in the past the furnace has been operated at a low rate of power input so as to avoid damaging the trough. This has resulted in low efficiency, small production, and a power cost per ton of metal melted which has made it difficult to compete with other more efficient electric furnaces, although it has in many cases shown decided savings over melting by fuel.

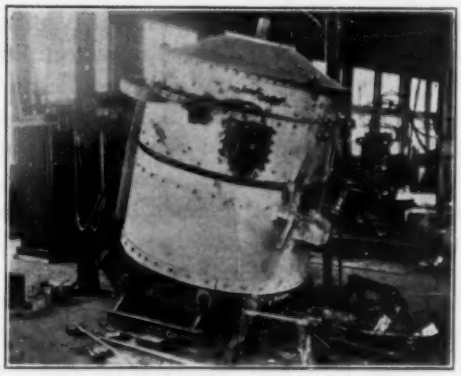

FIG. 3.—New form of Baily furnace.

But in the last two years this type of furnace has scarcely held its own, new installations hardly balancing old ones given up for one reason or another. There are some conditions where this type has advantages, and in the early days of electric brass melting it had more installations than any other. But, because of its low efficiency it now seems to be meeting with less favor. Moreover, another low efficiency furnace, the General Electric smothered arc furnace, which was handicapped in much the same manner as the Baily, has passed into "innocuous desuetude."

Some observers of the Baily furnace feel that the trough difficulties attending the use of higher power and hence higher trough temperatures are so great that this obvious method of increasing the efficiency cannot be satisfactorily used, and the furnace is still on the market in its original form. Mr. Baily is manufacturing a new form of this furnace (Fig. 3), in which he plans to increase the power input very greatly. He contemplates using up to 300 kw. on the furnace that formerly used only about 105.

[1] For Figs. 1 and 2 see *Jour. Amer. Ceram. Soc.*, **6** [4], 600, 601(1923).

Obviously, such a step will improve the efficiency markedly, and will equally obviously increase the refractory difficulties many fold. Recognizing this, the design of the new furnace, instead of supporting the trough on piers extending up from the hearth, supports it in a removable section just above the hearth, so that when the trough fails a spare section can be put in without long delay. The roof also is separate and replaceable. The hearth in the new type should show much the same life as in the old. The trough difficulties will be vastly increased and roof troubles somewhat. The new type has not yet been in operation long enough to secure quantitative data on refractory life, but the new design shows that refractory problems are expected to come up. The success or failure of the new type depends primarily on refractory performance.

The refractory life of the old type, run at low power input (105 kw.), was fair. The rammed hearth, of Corundite or of carborundum fire sand and fire clay or other refractories suitable for the purpose often melted 500 tons, but most hearths were torn out after smaller tonnages because the resistor trough had to be replaced more often and the users generally relined the hearth as well while the furnace was down. Such rammed hearths show some tendency to "float" and hearths built up as solidly as possible from brick appear to have given better results than the rammed ones.

The troughs gave from 125 to 500 tons, averaging perhaps 375 tons in the 105 kw. furnace. The Corundite or silica brick piers supporting the trough were sometimes injured in charging or by poking and some of the poorer results were due to such accidents.

The walls and roof, usually of Corundite, generally outlast several troughs. The Corundite is backed up by Sil-O-Cel.

In the early days the trough was rammed up in place, and such troughs often gave very short lives. The use of preformed sections remedied this considerably.

One user melting aluminum bronze in such a furnace, has used a hearth made up of ground fire brick, corundite clay and aluminum borings. The oxidation of the borings sinters the hearth together. 750 to 1000 tons has been obtained on such a hearth. The alloys melted contain aluminum, so a trace of that metal picked up from the hearth would do no harm, but such an expedient would be dangerous were the furnace required to melt the many types of brass, etc., in which the presence of small amounts of aluminum is fatal.

Moving Indirect Arc Type

The moving indirect arc type (Figs. 4 and 5)[1] has no weak spot in the refractories corresponding to the trough of the resistor type, but since the furnace oscillates or rotates, the lining is all hearth, and the problem of penetration by metal is an important one.

[1] *Jour. Amer. Ceram. Soc.*, **6** [4], 602, 603(1923).

Most of these furnaces are lined with fire brick high in alumina, Corundite being the usual choice, with Suprafrax also common. The Booth furnace has used a fire clay or Suprafrax lining with the whole cylindrical drum in one piece, for the smaller furnaces or two pieces for the one ton, furnace, with single pieces for each end, making a 3 or 4 piece lining. In the 250- and 500-pound sizes this is said to give about 125 and 250 tons, respectively, but some of the earlier users found the three piece lining decidedly unsatisfactory. Present opinion seems to be that these special linings do not stand up as well as brick in the larger furnaces, *i. e.*, over 500 pounds, and probably no better in the smaller ones, but they save some time in relining.

The Detroit furnace uses high alumina brick as standard, usually Corundite, sometimes Suprafrax. The furnaces have a Sil-O-Cel layer on the outside, and the larger ones usually have an intermediate layer of fire brick chosen for heat insulation rather than refractoriness. The intermediate layer is dispensed with in the 250-pound furnace. Although the power input is greater in respect to furnace volume and to weight of charge in the small furnace, the $4^1/_2$ inch Corundite lining backed up by $^1/_2$ inch asbestos cement and $1^1/_2$ inches of Sil-O-Cel appears to give as good or better life in heats than the $4^1/_2$ inch Corundite backed by $4^1/_2$ inch fire brick and $2^1/_4$ inch Sil-O-Cel in the larger furnaces. In 9-hour or "daylight" service, the efficiency of the small furnace, probably due to the smaller heat storage in the thinner lining, is almost up to that of the one-ton furnace. Some sizes use $6^1/_2$ inch Corundite, $^1/_2$ inch asbestos cement (to prevent metal that may penetrate the inner lining from getting into the Sil-O-Cel) and $4^1/_2$ inch bonded Sil-O-Cel.

There is a definite balance among the factors of furnace size, thickness of refractory, thermal conductivity of refractory, rate of power input and the number of hours used per day, which will give best results in the combined melting cost for power and for refractories. Further study of the problem may result in an even better balance of these factors.

The 250-pound furnace is a new size and full data on refractory life is not yet available, but the average will probably be well over 250 tons.

The 750-pound size, comparable in capacity to average sized furnaces of the induction type, is said never to have given a life of less than 375 tons, and the average is 500 to 600 tons. The one-ton size may give only 250 tons if the lining is abused in mechanical charging by dropping heavy ingots in from a considerable height without first placing a cushioning layer of borings. With care, however, the furnace should average 1000 tons, figures running from 600 to 2000. The lining life has steadily increased as users gain experience with the furnace, and as the makers are succeeding in impressing on the users the desirability of laying the brick tightly and without thick cement joints. Accurately fitting brick and close,

tight joints are very essential. Given well-fitting brick, the life of the lining is probably more dependent on the conscientious work of the brick layer than on any other factor.

Aside from the damage by careless charging, the failure of a lining is primarily due to penetration of metal into the lining. Not only does this damage the lining by expansion of the penetrated metal in heating up after it has frozen during the night, but it increases the thermal conductivity of the lining. The penetration of zinc vapor into the part which is the roof during the first part of the heat, before rocking starts, is as serious or more so than the penetration of liquid metal. The aluminous refractories generally fail by slow disintegration in the "roof" and in the un-washed ends, the process seemingly involving a spalling off of very minute particles, probably due to the entrance of zinc vapor, subsequent condensation, freezing when the furnace cools and expanding enough to cause this spalling when it is again heated.

This results in a gradual thinning away of the "roof" portion and finally the collapse of the inner course of the lining at that point follows. The "initial hearth" portion is less damaged than the "initial roof" portion.

It is probable that after 1500 heats, in any size furnace, the extra power required by permeation of the lining by the metal rises to a point where it would be cheaper to tear out a lining that might last 500 more heats, as more than the cost of the lining might be paid to the power company for radiated energy in the balance of its life. The average energy consumption over a period of 1500 heats is about 5% higher than with a brand new lining. The above figures refer to Corundite linings.

Some users have adopted Lawtonite, a refractory stated to contain about 40% fire clay and balance carborundum, although other sources of information report the refractory contains zirconia and carbon also. The cost is more than double that of Corundite. One user who was averaging 700 tons of red brass melted on Corundite, got 2700 on a Lawtonite lining. Others say that the life is doubled, while still others can see no appreciable difference. Lawtonite does not appear to stand abuse in charging any better than Corundite. On account of the greater thermal conductivity of carborundum, a Lawtonite lining will presumably show a slightly higher power consumption.

One user of a one-ton Booth furnace, after poor results in a four-piece lining, installed in August, 1921 a lining of Carbofrax (clay-bonded, high carborundum content) brick backed up by Corundite and in turn by Sil-O-Cel. This lining has been used in 24-hour service on 60:40 brass, is still in service, and looks good for an indefinite further period, after melting about 4000 tons. Beside the long life the lining is liked because zinc oxide or dross does not cling to it, and there is no accumulation to be fluxed out

at intervals. Although such a lining is expensive, the users say it has been a "wonderful investment." But they are careful to state that the lining has so much heat capacity and such high conductivity as to take a long time to heat up after the Sunday shut-down, and they believe that it would be quite as unsatisfactory in daylight service on the score of lower production and higher power consumption, as it is satisfactory on refractory life for 24-hour service.

The furnace uses an average of 290 kw.-hr. per ton on 60:40 brass in 24-hour service. The users do not consider this much higher than would be required with a Corundite lining. Since one-ton Detroit furnaces, Corundite lined, operating on 60:40 for only 16 hours a day have given long averages of 225 kw.-hr. per ton, it would appear that the remarkable refractory life is obtained at some sacrifice of efficiency and other users might conclude that the Carbofrax lining increased the over-all melting cost despite its long life.

The experiences with Lawtonite and Carbofrax bring up again the question of a graded brick, approaching Carbofrax in composition on the working face and approaching Corundite on the other, with the carborundum content decreasing uniformly from one side to the other. Some experimental work has been done on the production of these graded refractories.

The refractory problems of the moving indirect arc type furnace seem to be in fair shape. The furnace does not ordinarily go out of commission suddenly through refractory failure as is the case in the failure of the resistor trough of the Baily, and metal seepage into the lining has no effect on the electrical operation of the furnace, as it does in the induction furnace. The furnace can be turned so that any part of the circumference of the lining can be patched with the spot to be patched at the bottom, so that the patch is held in place by gravity while being sintered in. The moving indirect arc type shows fully as good a life in melting red brass as it does on yellow, some users say rather better, and even highly leaded red brass has no marked destructive effect.

Progress on this type will be made with a better balancing of furnace design with the properties of the refractories, in prevention of penetration of the refractories by metal, and by insisting on brick that can be fitted accurately and on fitting them accurately. The suitability of three-piece linings for the smaller sizes is still an open question.

Induction

The Ajax induction furnace (Figs. 6 and 7)[1] has had several hundred furnace-years' use on yellow brass, and the refractory problems on alloys high in zinc and low in copper (not over 75% Cu) are pretty well whipped. The resistor or

[1] *Loc. cit.*, **6** [4], 605, 606(1923).

secondary loop of the furnace, as shown in Fig. 8, is of peculiar shape, and this part is usually rammed up about a wooden form which is then withdrawn and a resistor ribbon slipped in and clamped together to form a solid secondary loop. Sometimes a brass form is used and left in place and current passed through it to dry the lining and later to melt the form, but this tends to crack the refractory due to expansion. Sometimes a form of paraffin in which a resistor is embedded is used, or a hollow sheet form of copper or brass used, either method avoiding expansion stresses. Some users air-dry the rammed-up shell and then heat it slowly in an oven before assembling the furnace and preheating it with a solid resistor within the loop. Others start heating by the resistor without air-drying, and have been able to start melting with the relined furnace 36 hours after the furnace was shut down, while the slower method takes a week or more.

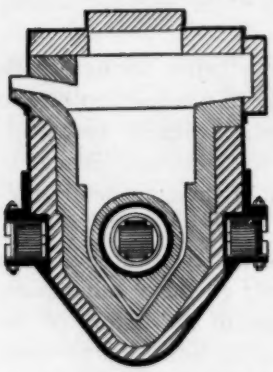

FIG. 8.—Section of Ajax-Wyatt furnace.

The refractory used for these rammed-in linings is an asbestos fire-clay mixture such as Johns-Manville asbestos cement No. 26 or 29, usually No. 26, or a similar mixture put out by the furnace makers. This seems to have the necessary properties of low thermal conductivity, some flexibility and ability to resist cracking due to the asbestos, and sufficient refractoriness for handling alloys with under 75% copper.

The usual rolling mill mixtures, containing under 3% lead, work all right with this lining, but alloys high in lead tend to give penetration.

The lining may fail either in infancy or in old age. Early failure is generally due to cracks, present before the first heat is made, or incipient and opening up soon. Since this type of furnace either melts 24 hours a day or has power kept on at night to keep the metal in the resistor loop melted, seldom or never being emptied and allowed to cool, there is a minimum of sudden temperature changes, and unless a crack is formed from steam pressure in drying out (the lining is mixed with the minimum of water for ramming) it should not crack thereafter.

The asbestos shreds tend to bridge an incipient crack and prevent molten metal from entering. If cracks do develop and metal works through them to the shell, so that a short circuit can occur the electrical conditions are disturbed and the furnace will no longer operate. In the early days a good many linings never completed the first heat, but with experience in ramming and drying out, early failure, though not absent, is more rare, and the rammed-up linings, in 60-kw. furnaces of 675 lbs. pouring capacity average at least 500 and probably 600 tons, and occasional lives of 3000 tons have been attained. One user gives the cost of lining, installed, as $90.

When the yellow-brass furnace linings die of old age, their failure is generally due to building up of incrustations of zinc oxide or dross in the resistor tube to such an extent that it can no longer be scraped out with high speed steel or nichrome tools used for this purpose, and chokes the channel so that the secondary is no longer of the proper size. Sometimes such cases can be helped by shifting to an alloy high in copper which has more scouring action on the tube and may clean it out.

Some users mix old crushed fire brick with the asbestos cement mixture for linings for yellow brass, but opinion is divided as to whether this is an improvement or otherwise.

Preformed linings of the shape shown in Fig. 9 have been tried out for several years in the Ajax furnace. Outside of one firm, no one seems to be using them now for either yellow or red brass. The superintendent of mechanical equipment of this one firm recently told the maker of the furnace that the preformed lining had been adopted at one of the plants and would be at all plants when the furnace shells were modified to allow it. A recent letter from the technical superintendent of the same firm to the writers states, however, that none but rammed linings are in use and that while the preformed linings had been tried out, all shops had gone back to the rammed linings.

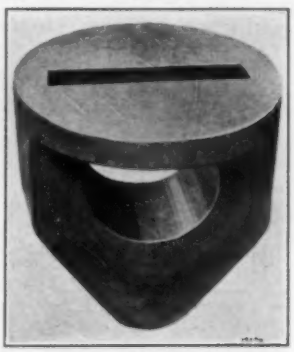

FIG. 9.—Preformed lining (resistor loop section) of Ajax Wyatt furnace.

The rammed asbestos cement (plus fire clay or ground fire brick) lining appears highly satisfactory for yellow brass. The temperatures required on the high zinc brasses are seldom over 1125°C or 2050°F and in the induction furnace the lining is not hotter than the metal.

The higher temperatures required for "nickel silver" or nickel brass and for red brass, sometimes going up to 1350°C or 2450°F play havoc with the asbestos-clay linings, for even though such linings may show a higher cone-test, in continued service they soften and allow metal to permeate them. Asbestos of course does not retain its flexibility but gets brittle at such temperatures, though it may still be a suitable bond. But for red brass the bulk of the mixture must be more refractory than for yellow and the lining must resist penetration by alloys that are more fluid than yellow brass is.

While the red brass (90 Cu, 10 Zn) of the rolling mill does not offer insurmountable difficulties, the red brass (85 Cu, 5 Zn, 5 Sn, 5 Pb) of the sand casting foundry and the other leaded alloys that must be handled, present worse difficulties.

Much work has been done on Ajax furnace linings for red brass in the effort to extend the field of the furnace beyond its proven one of yellow brass. The materials which best resist the action of the red metal seem to be fire-clay graphite (which involves rather too great heat loss), Thermolith (a chromite composition), Arcofrax (a high Al_2O_3 clay of the Corundite class) and Diamel ($MgO\ Al_2O_3$). A French type of three-phase induction furnace is said to use a fused sillimanite-alumina mixture with success. Magnesite has been tried in induction furnaces for red brass and found unsatisfactory. One rolling mill finds Thermolith the most satisfactory. A foundry running leaded red brass very hot with 8-hour melting with power on all night, has, besides many poorer results, obtained between 125 and 230 tons with an over-all average of perhaps 100 tons. The power consumption is 375 to 400 kw.-hr. per ton. Another plant, on 90 Cu, 10 Zn, could not get over 15 tons on an unstated lining, but with a refractory called Durastix, of composition unknown to the writers, got up to around 60 tons. Still another, on 90:10 with a rammed lining of composition also unknown, costing $150 installed, averages 125 tons. On nickel-silver this lining has given this plant a maximum of 100 tons.

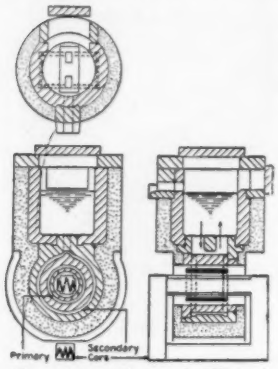

FIG. 10.—General Electric induction furnace. Sectional view showing the IFS-75 kw. repulsion induction furnace.

As the furnace maker states the problem, it is necessary to find a lining which will average upwards of 100 tons on red brass and give uniform life.

Users state that the failure of an Ajax lining on 90:10 occurs because of the lining becoming permeated with metal so that the lining about the resistor tube becomes conducting, the furnace takes too much power, beyond the transformer capacity, and the power factor drops way down. The thermal efficiency drops also so that while a new Ajax lining in 24-hour operation melts 90 : 10 at 285 kw.-hr. per ton the average is about 335 kw.-hr. per ton.

Though the users appear to consider a preformed lining as more convenient to install, the maker of the Ajax furnace appears more optimistic over the chances for a preformed lining for red brass than the users do. Since several materials withstand the action of red brass fairly well, the maker considers that the troubles are purely mechanical, connected solely with the design of the block and that these troubles will be eliminated by the cut and try process during a long series of tests already planned to be carried out with the coöperation of half a dozen users. The makers report that a lining embodying a new principle for which patent application has been made, has now been in use for a considerable time. They believe that such

lining gives promise of better performance than any lining heretofore used in the service of melting the high copper alloys known to the foundry trade as red brass.

General Electric Induction Furnace

The General Electric Co. recently put out an induction furnace of very similar design to the Ajax, but with a different form of resistor loop. (Fig. 10.) The General Electric uses preformed fire-clay blocks entirely, the shape being shown in Fig. 11.

These blocks are said by a user to cost $350 installed. One firm melting a yellow brass of 65 Cu, 33 Zn, 2 Pb on 9-hour operation finds the life to run from less than 85 tons, to about 350 tons with the average probably not better than the guarantee, which is put in days, but is equivalent to 85 tons in this case. The makers state that consistent results have not yet been attained, and ascribe it to uneven control of manufacturing conditions in making the refractories and therefore subject to correction, which is "expected to take place in the near future." Refractory manufacturers are in a better position than the writers to judge the chances of making good on such an expectation.

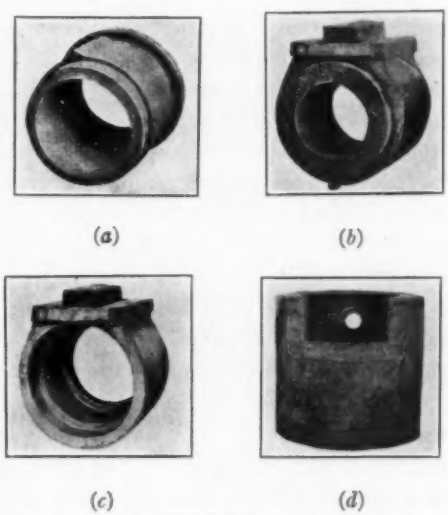

FIG. 11.—Preformed lining of G. E. furnace.
(*a*)—Inner refractory shell of heating chamber
(*b*)—Lower or heating chamber assembled
(*c*)—Outer refractory shell of heating chamber
(*d*)—Upper or melting chamber

Another firm, melting 90 Cu, 10 Zn, 24-hour operation, has obtained as high as 300 and 350 tons though most runs were very much poorer. The average melting rate throughout the life of the lining, which gets soaked with metal, was 365 kw.-hr. per ton, with the old width of slot in the resistor tube, *i. e.*, the furnace was some 10% less efficient than the Ajax although it was of larger capacity and used higher power input. With the new, narrower slot the efficiency of a General Electric furnace with new lining is stated to be slightly above that of the Ajax with a new lining, as would be expected because of the higher power input.

In the same sizes and with equal power input the two designs of induction furnace are not expected to show any difference in efficiency, though the General Electric is said to give only 55 to 60% power against 60 to 65% for the Ajax on 90:10 brass.

It appears that while the induction furnace with a rammed lining can melt yellow brass in 24-hour operation at 225 kw.-hr. per ton and at about 15 cents per ton for refractory costs, on red brass the power consumption runs over 300 kw.-hr. in 24-hour operation and around 375 kw.-hr. for 8-hour operation, with lining costs running from 65 cents in the best case to $10.00 per ton in the worst and an average of perhaps $1.20.

With a preformed lining on 90 : 10, 24-hour operation, the refractory cost may be as low as $1.00 per ton or higher than $4.00, with the average perhaps around $2.50.

On yellow brass, where the induction furnace lining problem is in good shape, that fact, the good efficiency on 24-hour operation, and the avoidance of electrode costs, make the induction furnace hard to beat, and it is only natural that the rolling mills which have adopted it for yellow metal should wish to extend its use to nickel silver, red brass and bronze in order to have uniform furnace practice on all alloys. However, there is a decided tendency on the part of the rolling mills to utilize Detroit, Booth, Bennett. or other electric furnaces for the higher melting, higher copper alloy because of the refractory troubles of the induction type. Unless the refractory situation is cleaned up this tendency is likely to continue.

The entrance of the induction furnace into the jobbing foundry field where 8-hour operation on leaded red brass is the rule, is not progressing very rapidly and most of the plants which are trying it out state that they consider it to be still in an experimental status.

In fact, in the work being done with the Ajax furnace on red brass, the expense of the experimentation with refractories is being borne by the furnace maker instead of by the user.

In such service the induction type is generally less efficient than the moving indirect arc type and there is only a slight margin in favor of the induction furnace on its cost of power plus labor per ton against the cost of power plus electrodes plus labor per ton for the arc type. At present the margin against the induction furnace on refractory cost is so great as to more than wipe out the margin piled up by its other advantages.

As the writers see it, the induction furnace makers will be forced to improve the refractory life on red brass and similar alloys very materially or else accept the present situation as inevitable and withdraw from that field.

Summary

Summing up the situation, the old type Baily furnace has some refractory troubles, worst in the carborundum trough, which will be accentuated in the new design, but these troubles will have to be accepted or solved if the efficiency is to be improved enough to keep that furnace in the running.

The Booth and Detroit furnaces do not have serious refractory troubles but have opportunity for marked improvement in efficiency by engineering

design calculated to make the most of the available properties of the refractories. Their most serious problem is in avoidance of penetration of the refractories by the metal, both as liquid and as vapor and in getting the bricks laid in proper fashion. The question of standard brick *vs.* large special shapes for the smaller sizes is not yet definitely settled.

The Ajax furnace has no serious problem in the refractory field for yellow brass. With the preformed lining, the General Electric furnace does have a problem there, and both furnaces, whether with preformed or rammed linings, have a problem of the first magnitude in the red brass field.

The question is, what can be done toward solving these problems? It would appear to the writers that since the question of metal penetration is very important something might be done by the application of electrically fused or otherwise fully preshrunk refractories, selection of refractories for low thermal expansion, and especially in the use of different sizes of grains so as to minimize voids and favor "close-packing" of the material.

Impregnation of the brick or of the rammed lining with hydrocarbons has been suggested, the idea being to fill the pores with the coke resulting from the decomposition of the hydrocarbon.

The problem has many sides. There is nothing gained by working out a refractory of infinite life if it is going to lose so much heat through the walls as to raise the energy requirements enough to pay for a cheap lining every few weeks. The cost factor is always present and the aim in the development of refractories must be to reduce the over-all cost of melting, and in this a multitude of factors have to be considered. No very prompt solution of the problem is to be expected, from its very nature. Most of these vitally interested are awake to the problem and are earnestly trying to solve it. The problem will work out in time, and the furnace user must draw on his stock of patience till he hits the solution, or till somebody else hits it and tells him about it.

The writers are inclined to think that the slow process of solution of the general problem would be accelerated if the furnace users would put on record either by detailed reports of the results of past experiments in the form of papers to some such SOCIETY as this; or, better, by submission of such reports to some committee which would sort and tabulate them. There have been enough experiments made to form a very useful foundation for future experiment, but data on them are available to very few people. Even the furnace makers, who have the most information, do not get all the data and they can gain from the experience of users of other furnaces and from the suggestions of refractory makers, if the refractory makers understand the problem in all its details.

BUREAU OF MINES, FIELD OFFICE
CORNELL UNIVERSITY, ITHACA, N. Y.

THE DEAD BURNING OF DOLOMITE.—IV[1]

By James Thomas Robson and James R. Withrow

Dolomite Bricks

Since member 2A14 gave all indications of being dead burned and contained but 10% of flux, it was decided to study the composition further as to its possibility for making regular size dolomite bricks, using 100-mesh dolomite throughout.

Hand molded briquettes about 5 x 2 x 2 inches were made of this composition. These were burned to cone 16 down. The bricks were set on chrome powder sprinkled over silica bricks, since no magnesite bricks were at hand.

It was found that a very slight dusting had taken place on the bottom, otherwise the bricks came out in very good shape. One of these bricks was tested in the hot water slaking test and remained there 20 days, after which time it broke into 4 pieces. The other bricks were placed outside in the air, where they have already remained for 15 continuous months without any alteration whatever.

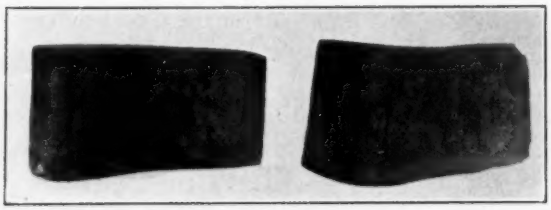

Fig. 32.—RA_{14} and R_1A_{14}.

Large sized bricks, $4^3/_8$ x $8^3/_4$ x 2 inches, of this composition were made by pressing the bricks out on a hydraulic press using 685 pounds per square inch pressure and 12% water for plasticity. These bricks were burned to cone 17 down and lost approximately 43.6% in weight on the dry weight basis. Both of these bricks cracked during burning. However, they were very firm and dense. They were burned on magnesite brick and no trace of dusting was noted where they came into contact with the magnesite brick.

One of these bricks was heated in an autoclave in water for 2 hours, during which time the gage pressure increased to 65 pounds per square inch. After this treatment the brick was unaffected. It was then again tested in the autoclave at 70 pounds per square inch gage pressure, for two hours at the end of which time it still remained unchanged. This brick RA14 has been standing in the laboratory for 15 months with no sign of alteration. The other brick R1A14 has been standing outside in the open air for the same length of time with no visible change having taken place. These two bricks are shown in Fig. 32.

Bricks from Calcined Dolomite

Brick XA14.—A batch of dolomite was calcined at cone 9. On treat-

[1] Published by permission of the Director, U. S. Bureau of Mines. See "The Dead Burning of Dolomite.—I," *Jour. Amer. Ceram. Soc.*, **7** [1], 61(1924); *ibid.*, II, **7** [2], 14; III, **7** [3], 207 (1924).

ment of this dolomite with hydrochloric acid, no traces of CO_2 were given off so that it was assumed that the dolomite was completely free from CO_2. According to the analysis of this dolomite, the CO_2 amounts to 46.8% by weight so that this amount was deducted from the batch weight which was made up as follows:

Dolomite calcined at cone 9.....	82.66%
Fe_2O_3.....	3.47
Al_2O_3.....	6.94
SiO_2.....	6.93
	100.00

Here it is seen that 82.66% of calcined dolomite with the above amounts of fluxes correspond to 90% of raw dolomite plus 10% of fluxes which is the composition of A14.

This batch was mixed with an excess of water and allowed to stand over night in order for the free lime to slake. It was then passed through an 8-mesh screen, sprinkled with H_2O and pressed into a brick about $8^3/_4$ x $4^3/_4$ x $1^9/_{16}$ inches in dimension, using 645 pounds pressure per square in. The water of plasticity on dry basis was 23%. This brick cracked considerably on drying.

Composition A14Y.—Determination of the true specific gravity of the raw dolomite by the pycnometer method gave 3.47. A batch of dolomite calcined to cone 5 gave a specific gravity of 3.08 by the pycnometer method, using kerosene as the immersion liquid. According to this specific gravity determination, 90 grams of raw dolomite correspond to 79.89 grams of this dolomite calcined at cone 5. A sample of this dolomite calcined at cone 5 gave no trace of CO_2 when treated with HCl and at cone 5 the dolomite should be completely free from CO_2 which would give a true specific gravity of 1.85. However, since the determinations for specific gravity checked at 3.08, it was decided to make up several batches assuming that only 11.2% loss in weight, as shown by the specific gravity, had occurred.

The following batch composition was made:

C. P. Fe_2O_3.....	2.23%
C. P. Al_2O_3.....	4.46
C. P. SiO_2.....	4.44
Dolomite calcined at cone 5.....	88.87
	100.00%

This composition is designated as A14Y.

Brick X1A14.—A brick was made of composition A14Y, again using 23% of water as in XA14. This water was added to the mix which was then allowed to stand for about one-half hour and then pressed into a brick $8^3/_8$ x $4^3/_8$ x $1^{13}/_{16}$ inches at 635 pounds pressure per square inch.

Brick X2A14.—This brick was made up of A14Y composition. About 34% of water was added and the mix allowed to stand in a humidor for about 20 hours. It was then screened through an 8-mesh screen and pressed at 370 pounds per square inch pressure into a brick $8^3/_4$ x $4^3/_8$ x $2^1/_8$ inches. This brick required only 200 pounds per square inch for forming because of the fact that it contained such a high per cent of water.

Small white particles of lime were noticeable throughout this brick.

Bricks X3A14, X4A14 and X7A14.—Made of composition A14Y except iron oxide analyzing 97.8% Fe_2O_3 was used in place of the 99.99% Fe_2O_3. This Fe_2O_3 was calculated to 100% Fe_2O_3 and the corrected amount used. Also, commercial Al_2O_3 and SiO_2 were used which in both cases analyzed over 99% pure. These bricks were pressed at 550 pounds per square inch.

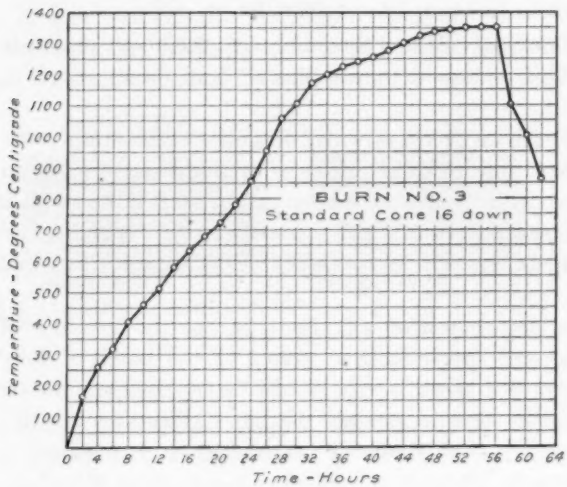

FIG. 33.

Bricks X5A14, X6A14, X8A14, X9A14, X10A14, X11A14 and X12A14.—These bricks were made of composition A14Y using 645 pounds per square inch pressure. They were mixed with different percentages of water as shown in Table IX, and pressed into bricks.

Raw Dolomite Bricks

Brick R2A14.—This brick was made of raw dolomite of the same composition as A14 using the C. P. oxides as fluxes. It required 12% of water for plasticity and 610 pounds per square inch pressure before it could safely be removed from the press mold without breaking. With 12% water of plasticity, it was found impossible to obtain a solid brick capable of handling with less than 610 pounds per square inch pressure.

Bricks R3A14 and R4A14.—Made of raw dolomite and used the 97.8% Fe_2O_3 and commercial Al_2O_3 and SiO_2, calculating all to the composition of A14. These bricks were treated with 12% of water, allowed to stand over night in a humidor and pressed into brick at 665 pounds per square inch.

The data regarding all these bricks are given in Table IX. They were burned to cone 16 down according to Fig. 33.

TABLE IX

Body	Pressure applied to mold. Lbs. per sq. in.	Per cent water of plasticity, dry wt. basis	Per cent volume drying shrinkage (plastic basis)	Condition after drying	Burning loss (dry wt. basis), per cent	Per cent volume burning shrinkage (dry basis)	Condition after burning to cone 16	Thickness of dry brick in inches
R2A14	610	12	4.6	O. K.	47.0	63.8	Cracked	$2^{7}/_{16}$
R3A14	665	12	8.6	O. K.	47.7	65.6	Very good	$1^{23}/_{32}$
R4A14	665	12	4.6	O. K.	47.2	65.1	Broken in middle	$1\ ^{7}/_{16}$
XA14	645	23	...	Badly cracked	....	....	Badly cracked	$1\ ^{9}/_{16}$
X1A14	635	23	2.7[1]	O. K.	....	....	"	$1^{25}/_{32}$
X2A14	370	34	6.5	"	....	64.6	"	$2\ ^{5}/_{64}$
X3A14	550	40	2.9	"	26.7	67.2	"	$2\ ^{1}/_{64}$
X4A14	550	40	0.9	"	24.2	68.4	"	$1^{23}/_{32}$
X5A14	645	40	2.3	"	26.2	72.5	"	$1^{21}/_{32}$
X6A14	645	40	2.5	"	26.9	72.0	"	$2\ ^{1}/_{16}$
X7A14	550	60	5.3	"	27.7	....	"	$1^{11}/_{16}$
X8A14	645	21	11.3[1]	"	26.8	70.0	"	$1^{15}/_{16}$
X9A14	645	40	2.9	"	29.5	73.7	"	$1^{23}/_{32}$
X10A14	645	45	5.1	"	28.7	70.4	"	$1\ ^{7}/_{8}$
X11A14	645	45	7.8	"	....	....	"	$1^{13}/_{16}$
X12A14	645	45	...	"	27.9	....	"	$2\ ^{1}/_{16}$

[1] Expansion.

The drying volume shrinkage and burning shrinkage were determined by calculating the volume of the bricks from the measurement of their thickness, width and length, both before and after drying and burning.

Results of Burn 3.—Brick R2A14 was cracked through into three pieces and had several horizontal cracks along the bottom side on which it was standing when burned. After standing for about 10 weeks, the bottom along these cracks broke into several small pieces. This brick was no doubt too thick to burn without cracking.

Brick R3A14 was in very good shape. It is a very dense and solid heavy brick, which after 15 months has shown no sign whatever of cracking or slaking in any way. Fig. 34 shows this brick; also R4A14.

Brick R4A14 was broken down through the middle. Otherwise, it resembled brick R3A14 very closely, which was of the same composition. After 15 months' standing in the laboratory, no visible change has taken place in this brick.

All bricks with prefix X on the designation mark, where previously cal-

cined dolomite was used in making the batch, were badly cracked after burning, and had many spots of dicalcium silicate throughout. After standing for about 28 days, all of these bricks slaked and disintegrated. Several of them, after standing in the laboratory and slaking for about eight months, are shown in Fig. 35.

The amount of pressure varied from 370 pounds to 645 pounds per square inch in making bricks with the calcined dolomite mixture, but since all of these bricks were badly cracked, the pressure applied evidently was of no help in preventing this cracking.

Table IX shows that, using raw dolomite, the necessary amount of water required to form bricks sufficiently strong to remove them from the mold without cracking or breaking is 12% of the dry weight of the mixture.

The loss in weight when burning the raw material was about 47%. The theoretical loss due to evolution of CO_2 when 90% of dolomite is present is 43%. This leaves 4% loss in weight, about 2% of which is probably due to the dehydration of the Al_2O_3 which combines with considerable water probably forming in some cases $Al_2O_3 \cdot 3H_2O$. This water of hydration is not lost until a temperature of 300°C is attainable. The other 2% is probably chiefly due to volatilization at the burning temperature cone 16.

FIG. 34.—R_4A_{14} and R_3A_{14}.

The burning volume shrinkage is about 65%, which is so excessive that it is practically impossible to make a brick of the raw material on a commercial basis without cracking. As noted, however, brick R3A14 is an exception.

Brick R2A14, which was $2^{7}/_{16}$ inches thick when dry, cracked very badly whereas R3A14 and R4A14, which were only $1^{23}/_{32}$ and $1^{7}/_{16}$ inches thick, respectively, showed a much greater improvement over the thicker brick R3A14, being perfectly solid, and R4A14 being cracked down through the middle. (See Fig. 34.)

Brick XA14 made of dolomite, calcined at cone 9, cracked badly on drying and hence was badly cracked after burning. This brick showed considerable dusting throughout, due to the dicalcium silicate, and after about three weeks it started to disintegrate. After 10 months' exposure in the laboratory, most of this brick had disintegrated.

The increased amount of water required for forming the calcined dolomite mixtures above that required for the raw dolomite mixtures is due to

the slaking or chemical combination of water with the free CaO and perhaps MgO in the calcined dolomite.

The loss in weight after burning averages about 27% in the case of the brick made from the calcined material. The theoretical loss due to driving off the chemically combined water from the double salt $Ca(OH)_2$-$Mg(OH)_2$ is 27.2%. Assuming this double salt to be 90% pure, as is the case with these bricks containing 10% of flux, the loss in weight should be 90% of 27.2=24.5%. The cause of the loss in weight of these bricks is thus chiefly due to the loss of chemically combined water and to a slight extent due to the fact that some of the water which combined with CaO was replaced by CO_2 while standing in the air before burning. This accounts for the fact that the loss in weight was 27% instead of 24%, as would be the case if no CO_2 were taken up by the lime.

Bricks X1A14 and X8A14 were made using only 23% and 21% of water for plasticity, respectively. On drying, these bricks expanded rather than contracted. The water content of these bricks was below 24.5%, which as explained above is the amount required for complete hydration of the CaO and MgO; hence all the water used no doubt went into combination, on standing, of the bricks, leaving no shrinkage water present. Hydration of lime causes expansion.[1] Where more than 24.5% of water was used, the excess shrinkage water present caused a much greater contraction than the expansion caused by the hydration of the CaO and MgO; hence the bricks contracted during drying.

FIG. 35.—Air slaked dolomite bricks.

The average amount of water of plasticity used for making these bricks of previously calcined dolomite was about 40%. In brick X7A14, 60% of water was used. This brick was so badly cracked after burning that its contraction could not be determined. This was also true with bricks XA14, X1A14, X1A14 and X12A14.

The effect of making these bricks under different pressures cannot be drawn from this study since all the bricks of XnA14 composition cracked after burning.

Bricks XA14, X1A14, X2A14 and X11A14 had pieces broken from them in the kiln and could not be weighed after burning.

In general, it is thus seen that bricks made from the dolomite calcined

[1] A. C. Davis, "Portland Cement," p. 201.

alone and then adding a flux is impractical due to hydration of the free CaO and MgO.

Bricks made of composition A14 using raw dolomite will no doubt be successful if some means can be found for overcoming the cracking which is due to the high shrinkage.

Burn 4.—Calcined Plus Raw Material

Several bricks and briquettes of composition A14 which had been exposed to the outside and inside slaking tests were ground to pass a 20-mesh screen.

This crushed calcined dolomite was mixed in a dry pan for two hours with raw composition A14 (100-mesh) in the proportions of 80% of calcined A14 and 20% of raw A14. Also a batch was made using 60% of calcined A14 and 40% of raw A14 composition. These were designated as R20CA14 and R40CA14, respectively.

These compositions were mixed with water and allowed to stand over night. After standing, they became very hard, showing that the calcined material A14 possesses hydraulic properties. These hard batches were then broken and rescreened through an 8-mesh screen. About 20% of water was added and the material pressed into bricks, using 1,000 pounds and 3,000 pounds per square inch pressure. After drying at room temperature for two days, the outside surface cracked badly in all cases. These cracks did not penetrate through the center of the bricks, but only about $^1/_4$-inch deep through the outside surface, which was hard and shell-like due to the fact that it was pressed denser than the inside which was soft and punky. These bricks were again crushed and screened to make the following bricks:

Brick R40C1A14.—One half of R40CA14 was treated with 22% of water, rescreened through an 8-mesh screen, allowed to stand 24 hours in a closed vessel and then pressed into a brick using 480 pounds per square inch. This brick was labeled R40C1A14. Although this brick dried without cracking, it was so fragile that when being lifted to place in the kiln, it cracked very badly throughout.

Brick R40C2A14.—This brick was made from the other half of batch R40CA14, using 12% by weight of thin coal tar and pressing at 480 pounds per square inch pressure. This brick, however, broke on handling after several hours' standing. It was then disintegrated by hand and after heating for about one hour over a Meker burner, it was treated with 12% of hot tar which when cold was much thicker than the previous tar used. (See analysis, p. 307). However, 12% of this heavy tar proved to be too much, since when pressed to 480 pounds per square inch pressure very little visible compression of the brick took place, due to the large amount of thick tar and when removed from the die, the brick was of

rubber-like consistency. This brick dried without cracking and could be roughly handled without harm.

Brick R20C1A14.—This brick was made of composition R20CA14 using 12% of the heavy tar analysis which is given below, and using 480 pounds per square inch pressure. This brick formed very well when pressed with the hot tar and dried without cracking, being very firm and solid, so that it could be easily handled.

Brick R20C2A14.—Composition R20CA14 was thoroughly mixed by hand with 7% by weight of powdered caustic magnesite made from Grecian magnesite calcined at 1000°C. The batch taken required 30% of water before it could be successfully molded. Although this brick dried fairly well without cracking, it was so fragile that when being set in the kiln, it cracked throughout.

TAR ANALYSIS

	Per cent		Per cent
Bitumen	77.88	Specific gravity at 25°C	1.237
Insoluble organic matter	22.05	Float test at 50°C	2.56
Ash	0.07		
	100.00		

Bricks X13A14 and X14A14.—As was mentioned in the description of the preparation of composition A14Y, it was thought that perhaps the dolomite calcined at cone 5 had been completely freed from CO_2, although the specific gravity determinations seemed to indicate otherwise. Since bricks made of composition A14Y, assuming that the dolomite was not completely decomposed, had all slaked down, a batch of the percentage composition A14 was made assuming that all the dolomite calcined at cone 5 was completely free from CO_2. This percentage composition corresponds to that of XA14 previously mentioned. It was molded into brick X13A14 using 550 pounds per square inch pressure and brick X14A14 which was molded by hand after a sufficient amount of water had been added to make it soggy-like. The amount of water in each case was not measured. Brick X14A14 dried without cracking, while brick X13A14 dried fairly well, but had two small cracks in the center. However, no further cracking occurred with rather rough handling of the bricks.

Calcined Material

Compositions A14, D6 and D9.—Batches of composition corresponding to A14, D6 and D9, all of which stood up against slaking in the air and water, were made. These were calcined to remove all of the shrinkage and then made into large size brick.

The A14 and D6 batches were made by tempering with water into small balls about $1\frac{1}{2}$ inches in diameter. Batch D9 was made into small

circular plaques about $2^1/_2$ inches in diameter and $^1/_2$-inch thick. This was done to determine whether or not the thinner plaques could be more thoroughly calcined than the balls. These were dried and calcined to cone 17 in Burn 2.

The compositions on dry basis of these batches in which C. P. fluxes were used are as follows:

A14		D6		D9	
Raw dolomite	90.00	Raw dolomite	85.00	Raw dolomite	85.00
Fe_2O_3	2.00	Fe_2O_3	9.00	Fe_2O_3	6.00
SiO_2	4.00	SiO_2	6.00	Al_2O_3	3.00
Al_2O_3	4.00	Al_2O_3	0.00	SiO_2	6.00
	100.00		100.00		100.00

Composition A14C.—A batch of A14 composition, using commercial materials for fluxes, was also calcined. In this batch North Carolina kaolin of analysis given below was used as the source of SiO_2, some Al_2O_3 and a slight amount of Fe_2O_3. For the deficient Al_2O_3, commerical Al_2O_3 analyzing over 99% pure was used. For the iron, Fe_2O_3 analyzing 97.8% Fe_2O_3 was used. The batch weight follows:

Raw dolomite	88.65
Fe_2O_3	1.92
N. C. kaolin	8.76
Al_2O_3	0.67
	100.00

This batch was mixed with water and molded by hand into a briquette about $1^1/_2$ x 3 x 5 inches and also into smaller briquettes about 1 x 1 x 3 inches. These briquettes dried without cracking.

ANALYSIS OF NORTH CAROLINA KAOLIN

Ign. loss	16.54
SiO_2	45.17
Al_2O_3	37.35
Fe_2O_3	0.60
TiO_2	0.03
CaO	trace
MgO	trace
K_2O	0.70
	100.39

Composition D9C.—This batch was made of the same materials as used in composition A14C, except that all of the Al_2O_3 was added in the form of North Carolina kaolin and the deficient SiO_2 was added as commercial flint.

The batch recipe follows:

Raw dolomite.....	83.85
Fe_2O_3.....	5.87
N. C. kaolin.....	7.95
SiO_2.....	2.33
	100.00

The batch was mixed with water and two briquettes $1^1/_2$ x 3 x 5 inches were molded by hand. These dried very well without cracking.

Results of Burn 4

The burning chart for this burn is given in Fig. 36. In this burn cone 17 was down in the front of the kiln and cone 17 was in the 3 o'clock position in the back of the kiln.

Brick R40C1A14.—This brick came out of the kiln badly cracked and bloated. It had a dull-like appearance. The shrinkage was not excessive. (See Fig. 37.)

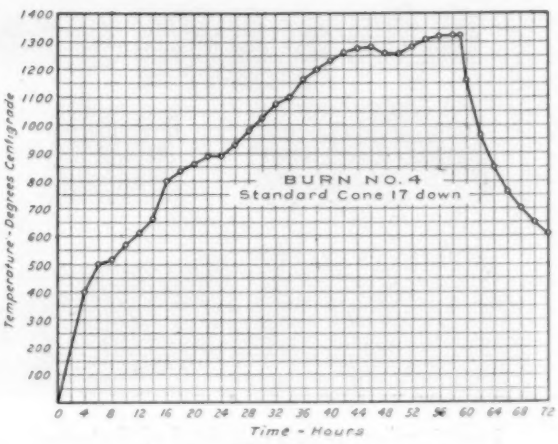

FIG. 36.

Brick R40C2A14.—This brick was distorted and badly cracked longitudinally through the center parallel to the face of the brick and also vertically down through the center. The cracking in this case appears to be due more to the method of pressing rather than due to shrinkage which was not excessive. One face of the brick was perfectly smooth and intact so that probably the burning out of the tar binder did not cause all of the cracking, although the vertical disruption appears to be due to this. (See Fig. 37.)

Brick R201CA14.—This brick was very badly cracked, broken in two, and bloated. This appears to be due to both the method of pressing and the tar used as a binder. (See Fig. 37.)

Brick R20C2A14.—This brick, made using caustic magnesia as a binder, had many cracks, mostly just on the surface. These cracks were formed while the bricks were being set in the kiln, the caustic magnesia not hardening sufficiently to make a tight bond. (See Fig. 37.)

Brick X13A14.—This brick had a few cracks which were formed while drying, but evidently did not have any cracks due to burning. This brick was warped. It was very dense, solid and almost glassy appearing. More bricks of this composition were made in the next burn in order to further study its adaptability as a refractory. No dicalcium silicate formed on this brick after standing in the air for 75 days. (See Fig. 37.)

Brick X14A14.—This brick had a surface similar to X13A14, but was badly cracked and disrupted. No dicalcium silicate formed on this brick upon standing for 75 days.

These bricks show that it is possible to dead burn previously calcined dolomite if sufficient flux is present. (See Fig. 37.)

Calcined Material.—All of these compositions calcined very well except the large briquettes of D9C, about one-half of which dusted down in the kiln. The large briquettes of A14C, however, where the commercial materials were used, proved to be very satisfactory, no sign of dusting or cracking occurring. (See Fig. 37.)

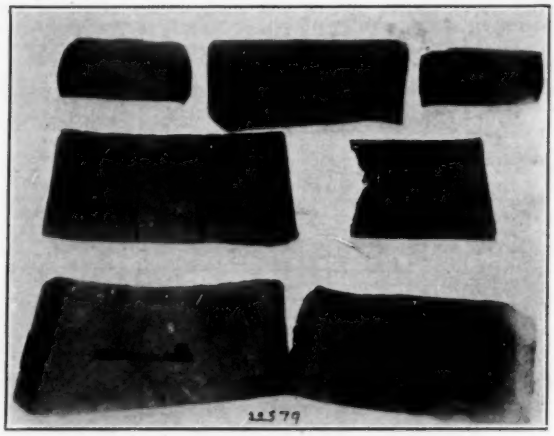

FIG. 37.—Top row, left to right, $A_{14}C_1X_{13}A_{14}X_{14}A_{14}$
Middle " " " " $R_{20}C_2A_{14}$, $R_{20}C_1A_{14}$
Bottom " " " " $R_{40}C_2A_{14}$, $R_{40}C_1A_{14}$

General Conclusions of Burn 14

The use of tar as a bond appears to be of no value, especially when part of the dolomite mixture has been previously calcined. In preparing dolomite-tar mixtures for basic converter linings, Backheuer[1] found that sintered dolomite cannot be used since it prevents absorption of the tar.

The use of water alone in forming bricks of the calcined plus raw material appears to be impossible because of insufficient bonding strength.

Caustic magnesia made from the Grecian variety does not exercise much bonding effect on calcined A14 composition.

Whether or not it is advisable to use a mixture of raw dolomite composition plus calcined dolomite composition cannot be decided from this brief

[1] "The Preparation of the Dolomite-tar Mixture in Thomas (basic converter) Steel Works," *Stahl u. Eisen*, **41**, 954 (1921).

study, although this method of using previously calcined A14 composition, of course, did decrease much of the shrinkage during burning.

Further work done to determine the feasibility of using the calcined dolomite such as composition X13A14 as a suitable material shows it to be impractical. (See Burn 5.)[1]

In using calcined dolomite and then adding the fluxes, a brick molded under high pressure appears to be better than a hand-molded brick.

All of the compositions A14, D6 and D9 will calcine without dusting.

In composition A14 it appears to be possible to use North Carolina kaolin as one of the fluxes in place of free flint and some of the alumina. This kaolin is, of course, much cheaper than the pure oxides for which it is substituted.

Kaolin when used as a flux in composition D9 appears to cause excessive dusting and hence cannot be used.

All calcined bodies seemed to be burned completely through to about the same degree of vitrification so that the shape or thickness used within the limits herein is immaterial for calcining.

To be continued)

[1] Description of Burn 5 will be given in *Jour. Amer. Ceram. Soc.*, May, 1924.

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[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

Abrasives

Abrasives. Statistics, 1919-1921. ANON. *Imperial Min. Res. Bur., Min. Ind. Brit. Empire and Foreign Countries* (1924).—This report gives: world's production, summary of exports and imports of abrasives, details of imports and exports of the United Kingdom, Union of South Africa, Canada, Hong Kong, Australia, New Zealand, France, Germany, Greece, Switzerland, and the United States, concluding with a bibliography. O. P. R. O.

The marundites and allied corundum-bearing rocks in the Leysdorp district of the eastern Transvaal. A. L. HALL. *Trans. Geol. Soc. S. Africa*, **25**, 43–67(1923).—Marundites are rocks consisting essentially of margarite and corundum (whence the name) forming small vertical intrusives up to a few yards thick in pyroxenite, peridotite, and serpentine. Marundite may pass into plumasite (andesine-corundum-anorthosite) within the same rock body. Abnormal marundites are characterized by cyanite, Cr-mica, and a granular ruby-colored mica; but this type is known *in situ* at but one locality. The marundites are regarded as having been derived from quartz-feldspar pegmatites intrusive in magnesian rocks through the gradual removal of SiO_2 leading ultimately to a magma supersatd. with Al_2O_3, which sepd. out as corundum. The relative amt. of SiO_2 removed dets. whether plumastite or marundite is formed, and this is believed due to pneumatolytic conditions. These changes may occur *in situ* or prior to intrusion. The abnormal cyanite type probably arose under similar genetic conditions, perhaps prior to intrusion, and disturbed by the assimilation of accidental xenoliths. Analyses are given of margarite, marundites and plumasites. Cf. *Ceram. Abs.*, **1** [12], 317(1922). S. G. G. (*C. A.*)

PATENTS

Sand-paper, emery cloth, etc. MINNESOTA MINING AND MANUFACTURING CO. Brit. 194,274, Feb. 6, 1923. Waterproof sand-paper, emery cloth, or like material, comprises a base upon which the abrasive powder is secured by a non-hygroscopic cement or binder. The binder is in the form of a varnish prepd. from linseed oil or china wood oil and a gum, *e. g.*, kauri, copal, or dammar, and to which a drying agent, *e. g.*, Mn borate, is added. To accelerate the drying, and to improve the adhesive properties of the binder, electrolytic process white lead, known as "Dowdy white," is added; a paste drier, *e. g.*, $Pb(OAc)_2$ and resinate of Mn also may be employed. When a more fluid binder is required, a japan drier is used, *e. g.*, "schrack japan." In prepg. the *varnish*, the oil is boiled until it nearly reaches a solid state, and the varnish may comprise 3 parts of gum dammar with two parts of linseed oil. Castor oil may be incorporated with the varnish when the drying action is required to be retarded. After completion of the abrasive sheet, the base may be thinned down to give greater flexibility. The binder is applied under pressure. (*C. A.*)

Homogeneous crystalline products. H. A. RICHMOND and R. MACDONALD, JR. Can. 234,502, Sept. 25, 1923. A refractory, insulating and abrasive product characterized by great hardness, solidity, resistance to fracture and fine crystn. is composed of oxides of B, Al, Si, Fe and Ti fused together. (*C. A.*)

Art

Decorative painting on glass. MAURICE DE KEGHEL. *Rev. prod. chim.*, **26**, 645–8, 721–4, 759–60(1923).—A general discussion of the glasses, colors and especially of the vehicles suitable for painting on glass. A. P.-C. (*C. A.*)

Cement, Lime and Plaster

A new rapid hardening slag cement. R. M. *Rev. Mat. Constr. Trav. Pub.*, **172**, 1–4(1924).—A slag cement "Louve" having rapid hardening properties has been per-

fected by Pierre Prévost in France. Chem. analysis in wt. %: SiO_2 (uncombined) 1.2, SiO_2 (combined) 24.2, Al_2O_3 13.8, Fe_2O_3 1.6, CaO 46.3, MgO 2.4, SO_3 0.9, undetd. 9.6. The "hydraulic index" is 0.83; fineness of grinding, residue on 80-mesh screen (900 mesh per sq. cm.) 1%, residue on 180-mesh screen (4900 mesh per sq. cm.) 10%; apparent d. 0.880. The cement sets slowly, beginning 5 hours after tempering, and ending 8 and 15 hours later. The following are results of tests made for comparison between the "Louve" cement and the prevailing cements acceptable according to the specifications of the city of Paris.

TENSILE STRENGTH (KGS. PER SQ. CM.)

Neat Cement	24 h.	2 d.	7 d.	28 d.	3 m.	6 m.
"Louve" cement	17	24	29.7	32	36.5	40
Av. slag cement	..	7	20	26	28	30
Dry Mortar 1:3						
"Louve" cement	13	18.6	27.5	31.3	34.5	35
Av. slag cement	..	6	16	25	29	32

CRUSHING STRENGTH (KGS. PER SQ. CM.)

(1) Compn. 150 kgs. cement, 1 cu. m. gravel (20–40 mm.), 1/2 cu. m. sand

	18 h.	24 h.	48 h.	7 d.
"Louve" cement	3	5.2	18.5	27.5
Av. slag cement	..	2.7	4.2	21.9
Av. Portland cement	..	...	9.0	21

(2) Compn. 350 kgs. cement, 1 cu. m. gravel (5–20 mm.), 1/2 cu. m. sand

	18 h.	24 h.	48 h.	7 d.
"Louve" cement	7.9	9.7	18.8	38
Av. slag cement	3.2	4.2	6.2	25

By the use of a rapid hardening cement road-work is accessible to traffic in a short period of time. L. N.

Magnesium oxy-chlorides, their properties and uses in the construction field. M. Y. SEATON. *Tr. Am. Inst. Chem. Eng.*, **14**, 305–19(1922).—Magnesium oxychlorides, discovered by Sorel in 1867, have become an important structural binding material for compn. floors, wall stuccos, special molds for castings, etc. These bodies are made by treating with a dil. soln. of $MgCl_2$, a mixt. of MgO and an aggregate composed of fine sand, ground silica or marble, and a fibrous mat. such as asbestos or wood fiber. When applied to walls or floors they dry quickly to light and strong bodies which are sanitary, dustless and resistant to wear. The $MgCl_2$ comes chiefly from the salt brines of Michigan. The magnesium oxide used is made by calcining magnesite, obtained from the California and Washington deposits. Calcining in rotary kilns, with temp. carefully controlled at around 1100°C is the best practice. The plastic calcined oxide is ground to give 85% through 200-mesh. Increased demand in the future may be satisfied by plastic MgO made from dolomite. The sand used should be clean, and finer than concrete sand. The prepn. of the mixes is rather complicated and demands careful control so that it is not ordinarily practicable to prep. them at the point of use. The bodies will withstand water provided there is proper drainage, with no stagnant water in contact with them for long periods. Cf. *Ceram. Abs.*, **2** [7], 147(1923). B. M. L.

Gypsum. F. A. WILDER. *Mineral Ind.*, **31**, 354–60(1922).—The output of gypsum products and their value in 1922 was the greatest in history. The use of gypsum for land plaster, partitions, roofs, floors and plaster board is increasing. Many new

groups and trade affiliations appeared during the year. The use of rotary calciners of the Port. cement type was an outstanding feature. Ball mill grinding is becoming more common in connection with rotary kilns. In the Emley process, plaster of Paris is ground in ball mills, thereby driving out the chem. water. Recombining in the mill makes hard wall plaster denser and more plastic. Ready cut steel frame houses covered inside and outside with plaster board, and the floors and roofs made of gypsum are being erected in Canada. Outside bearing wall in another type of construction are being made of gypsum tile. Cf. *Ceram. Abs.*, **1** [6], 160(1922); *ibid.*, **1** [3], 91(1922). T. N. McV.

The energy of crystallization of burned gypsum. M. von Glasenapp. *Z. anorg. allgem. Chem.*, **130,** 246–52(1923).—The setting of gypsum is due to recrystallization as the dihydrate, following soln. of the hemihydrate. The resulting change in structure is illustrated by photomicrographs of the original and regenerated gypsum; the latter is composed of much finer crystals, is harder and more porous. Setting in water vapor only produces similar effects, with even finer crystals. (Cf. *Ceram. Abs.*, **2** [11], 239 (1923). B. H. C. (*C. A.*)

The scientific investigation of cement. Richard Grün. *Beton u. Eisen*, **22,** 281–3(1923).—An historical review and illustrated description of the new German institute for cement research. C. C. D. (*C. A.*)

Fused cement. A. Troche. *Beton u. Eisen*, **22,** 271–6(1923).—The properties of the recently developed high temp. cement (elec. cement, ciment fondu, etc.) are described, with extensive data (cf. *C. A.*, **15,** 583; **16,** 1845; 3374; **17,** 195, 619, 3739, 3409). C. C. D. (*C. A.*)

Bibliography of magnesian cements. G. H. West, R. L. Sebastian and W. A. Darrow. Bur. of Mines, *Repts. of Investigations*, No. **2534,** 17 pp.(1923).—211 titles. E. J. C. (*C. A.*)

Fused cement, electric cement, or aluminous cement. Ch. Bertin. *Bull. soc. ind. Rouen*, **51,** 339–43(1923).—Brief description of fused cement (invented by Bied) and of its merits, the chief of which are rapid setting and hardening (forms can be safely removed after 12 hrs.), high tensile and compressive strengths, and resistance to the action of sea water and sulfates. A. P.-C. (*C. A.*)

Lime in 1922. G. F. Loughlin and A. T. Coons. U. S. Geol. Survey, *Mineral Resources of U. S., 1922*, Pt. II, 195–206(preprint No. 23, publ. Dec. 1, 1923). E. J. C. (*C. A.*)

Gypsum in 1922. K. W. Cottrell. U. S. Geol. Survey, *Mineral Resources of U. S., 1922*, Pt. II, 133–9(preprint No. 16, publ. Oct. 18, 1923). E. J. C. (*C. A.*)

Enamel

PATENTS

Red cupriferous pigment for iron enamel. R. T. Hansen. Danish 30,646, Nov. 13, 1922. A mixt. of $CuSO_4$ soln., tin-putty and gum arabic with a diminutive addn. of $AuCl_3$ or cinnabar. (*C. A.*)

Operating muffle furnaces. F. G. Roberts. U. S. 1,472,401, Oct. 30. Muffles such as those used in firing enamel ware are kept continuously up to working temp. by simultaneously heating both the interior and exterior of the muffle. (*C. A.*)

Glass

The estimation of selenium in glass. A. Cousen. *Jour. Soc. Glass Tech.*, **7** [28], 303(1923).—A modification of Frankel's process. J. G. P.

The production of colorless glass in tank furnaces with special reference to the use of selenium. II. A. Cousen and W. E. S. Turner. *Jour. Soc. Glass Tech.*, **7**

[28], 309(1923); for Part I see *Ceram. Abs.*, **1** [5], 94(1923).—A very large number of small scale meltings were made in further elucidation of the behavior of selenium and sodium selenite during the decolorizing of glasses prepd. either from batches contg. soda only, or with small additions of salt cake, sodium nitrate, borax, or arsenious oxide. With batches contg. soda ash only, $^1/_2$ oz. of selenium per 1000 lb. of sand is more than sufficient to decolorize glass which contains only .04 to .06% of iron oxide, the glass becoming yellow as a result of the selenium excess. The presence of sodium nitrate does not prevent the liberation of selenium in glasses prepd. from batches contg. this salt, and they are colored much more intensely yellow or brown than soda ash glasses under corresponding conditions. The development of a yellow or brown color in glasses contg. selenium or sodium selenite is dependent on the time of heating as well as on the amount of selenium present. With glasses prepd. from soda ash batches or containing sodium nitrate, the yellow color deepens to brown when the glass is maintained for a period of hours at temps. between 1380°C and 1300°C. In batches containing salt cake, however, the color changes from yellow or pink to green, owing to the very small amt. of selenium retained in these batches and to the natural increase of iron oxide content as the glass stands in contact with the fire clay. A small amt. of borax equivalent to the yield of 1% of B_2O_3 in the glass was found to be without effect either on the amt. of selenium retained or upon the color of the glass as compared with pure soda ash batches only. Arsenious oxide in the propn. of 1.5 parts to 1000 of sand prevented the yellowish brown color due to selenium, even when an excessive amt. of the latter was added, and even when the glass was maintained for a considerable period at 1380–1300°C. Arsenious oxide is the only substance so far discovered which makes easy the decolorizing of selenium-contg. glasses and gives stability to the conditions. Analysis of the glasses for selenium showed that the greater part is lost by volatilization, a commercial glass only retaining 23% of that added. Batches which contain sodium nitrate being more readily fusible, retain considerably more selenium than those which produce glasses more slowly. The amt. of selenium actually needed for the operation of decolorizing appears to be exceedingly small. From indications so far obtained, it would appear that the selenium added to a batch does not become oxidized to selenite, but remains as selenium, its color only being developed slowly as the result of continued htg. J. G. P.

The refractive index changes in optical glasses occasioned by chilling and tempering. F. TWYMAN AND F. SIMEON. *Jour. Soc. Glass Tech.*, **7** [28], 262(1923).—A discussion. J. G. P.

Opaque and colored glasses and ceramic glazes of the same nature. ALBERT GRANGER. *Jour. Soc. Glass Tech.*, **7** [28], 291(1923).—A discussion in which the author demonstrates that the old purely chem. conceptions which have been applied to glass and to glazes are totally insufficient. One must accept the idea of a soln. in many of those cases wherein one formerly allowed the intervention of a compd., the actual existence of which was doubtful from the observed facts. J. G. P.

Pyrex glass as a material for chemical plant construction. A. E. MARSHALL. *Trans. Amer. Inst. Chem. Eng.*, **14,** 329–43(1922).—An outline of the development of Pyrex glass for large-scale plant equipment is included. The cleanliness, ease of inspection and observation, and resistivity to corrosion of glass equipment gives it many advantages wherever it is possible to use it. Pyrex has a very low expansion coeff., and a softening point of about 800°C. Denitrating towers, large evapg. dishes and retorts, tubing, high-tension insulators, etc., are among the articles made successfully from Pyrex glass. B. M. L.

Glass rings. A new filling material for towers. F. C. ZEISBERG. *Trans. Amer. Inst. Chem. Eng.*, **14,** 321–7(1922).—Hollow cylinders or rings have been shown to be

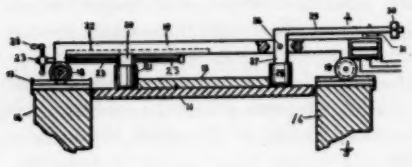
very efficient for packing towers. They are now being made of stoneware but the smallest sizes practicable using such material are bigger than desirable for many uses. Small metal rings now made present such a large surface that any chemical reaction with the liquids and gases present results in rather severe corrosion of the metal. The DuPont Co. has developed glass rings for packing to the point of fairly cheap quantity production. These can be made as small as necessary, give good service for certain purposes and are easily cleaned. Properties and tentative prices for the sizes made are given. B. M. L.

Heat economy in the glass industry. ANON. *Arch. Wärmewirtschaft*, **4**, 159–60 (1923).—A description of the diagnosis of typical cases of fuel squandering in glass works. The causes were: air leaks into regenerative chambers; excessive steam in the producers; too low a fuel bed in the producers; leaky reversing valves; too little draft in the producers; too infrequent clinkering. E. W. T. (*C. A.*)

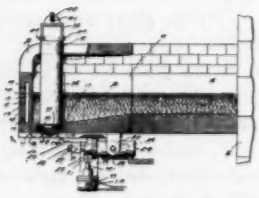
Simple and accurate method for determining surface tension and density of molten glass. EDW. W. WASHBURN. *Proc. Am. Phys. Soc.*, **1922**; *Phys. Rev.*, **20**, 94–5 (1922).—The surface tension of molten glass is detd. from the positions of a Pt cylinder suspended by a sensitive spring free in air and after raising a small pot of molten glass so that the surface of the glass makes contact with the cylinder. The cylinder is standardized before and after each detn. by similar measurements with liquids of known surface tension. The d. is detd. with the same app. but with a Pt sphere substituted in place of the Pt cylinder. The surface tension of the soda-lime-silica glasses between 1200° and 1450° is of the order of magnitude of 150 dynes per cm. D. MACR. (*C. A.*)

PATENTS

Glass machinery. CLARENCE W. AVERY and WENZEL G. VESEY. U. S. 1,482,106, Jan. 29, 1924. In a glass width regulator for glass strip forming machinery having a moving platform with strip forming members associated therewith, a frame adapted to be moved transversely of the line of movement of the platform by a strip formed on the platform, an adjustable stop on said frame and a movable stop on said frame whereby the strip passing between the stops may cause the frame to vary its position relative to the platform, the adjustable stop may determine the width of the strip formed on the platform, and the movable stop may be actuated by variations in the width of the strip to vary the speed of the platform.



Glass-delivering apparatus. JOHN W. CARNAHAN. U. S. 1,481,688, Jan. 22, 1924. The combination with a glass fur. snout having a discharge opening, of a knife cutting off the glass discharge through the opening, and means for shifting the knife transversely across the opening and then lowering the knife away from the discharge opening and returning it to its initial position. The combination with a glass fur. snout having a discharge opening in its bottom, of an annular bushing of refrac. mat. disposed in said discharge opening and through which the glass passes, a metallic plate in the bottom of the snout having an outwardly and downwardly flared opening larger than the opening of the bushing, means for cooling said plate, a vertically shiftable plug disposed within the snout and having its lower end reduced to form a portion fitting the lower end of the bushing, a shoulder above said bushing adapted, when the plug is lowered, to rest on the bushing and cut off the flow of glass therethrough, the lower end



of the plug having the form of an inverted cone, and a knife disposed against the metallic plate and reciprocable across the axis of the opening therethrough and below the conical lower end of the plug when the latter is lowered to thereby cut off the thread of glass depending from the extremity of the plug when the plug is lowered.

Ornamenting glass, etc. G. L. HUYSMANS. Brit. 199,802, March 28, 1922. Raised designs or inscriptions are produced on glass, pottery, etc., by the application of a plastic compn. consisting of finely powd. metals, such as Cu, Al and Mg, mixed with an emulsion of $CaCO_3$, a thick soln. of mucilage such as Senegal gum, copal, $Al_2(SO_4)_3$ and coal tar or drying oil. The compn. hardens without high temp. baking. A suitable method of applying the compn. is by extrusion app. The leads of stained glass may be imitated by this process. (*C. A.*)

Bottles; silvering. H. FERGUSON. Brit. 200,448, Jan. 25, 1923. A bottle is made in the shape of a revolver or pistol and the inner surface is coated with Ag, etc., by the "formaldehyde" or other known process. The muzzle forms the neck of the bottle and may receive a cork or stopper. In the method of coating described, 3 aq. solns. are poured into the bottle in turn, the first consisting of cryst. $AgNO_3$ and NH_3, the second of HCHO, and the third of 1 part by vol. of the first soln. with 2 parts of the second. The coating is then washed with distd. H_2O. (*C. A.*)

Glass manufacture. CORNING GLASS WORKS. Brit. 194,888, Feb. 7, 1922. A decolorizer for use with borosilicate glasses consists of Nd_2O_3. About 0.5 to 1% of the decolorizer is added to the batch to neutralize the yellow green tint of the glass due to the presence of Fe. The product commercially known as "didymium oxide," which is a mixt. of Nd_2O_3 and La oxide, is used. The amt. of Nd_2O_3 may be increased to 5% if it is desired to produce a pink color in the glass. (*C. A.*)

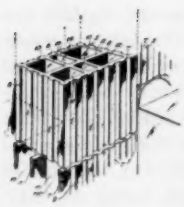
Glass manufacture. CORNING GLASS WORKS. Brit. 195,495, Feb. 7, 1922. A process of making translucent or opaque glass consists in melting a batch contg. boric oxide, a relatively high % of SiO_2, and a chloride, bromide, or sulfate. Preferably, the boric oxide content of the batch is not less than the alkali content, and the SiO_2 is over 70% of the ingredients other than the chloride, bromide, or sulfate. In practice, 1 to 5 parts of a chloride, bromide, or sulfate, preferably of an alkali metal, are added to 100 parts of a suitable foundation glass or its batch. The compns. of a no. of suitable foundation glasses are given in the specification. (*C. A.*)

Heavy Clay Products

British test road. ANON. *Roads and Road Construction* (London), **1**, 395(1924).—An appeal has been made for a test road in England such as has been constructed in various places in America. The proposal is to make a mile of road using 8 types of foundation and 8 types of surface finish and it will be tested to destruction by the continuous running of loaded motor lorries over it. The results would produce facts for the highway engineer to embody into his specif. which would be of untold value and mean great economy in construction work, in as far as it would show how to avoid mistakes. O. P. R. O.

PATENT

Hollow building tile. EDWIN J. BEINECKE. U. S. 1,481,249, Jan. 22, 1924. A wall structure, comprising superimposed courses of cellular tiles having front, back and side outer walls, inner walls extending from front to back, and from side to side, forming front and back passages in said tiles, the front passages being of less area than the back passages, the opposite ends of the tile of one course lying in substantially parallel planes, the upper ends of the tile of an adjacent course having a front reduced portion, the front and back outer walls of the several courses of tile being arranged in alignment with each



other, the inner front and back connecting walls of one course of tile being arranged in staggered relation to the corresponding walls of a vertically adjacent course, and a facing composed of courses of stringer bricks and an intermediate course of header bricks, the inner ends of the header bricks overlapping the reduced portion of the upper end of one course of tile and being bonded therewith on the upper end of the front wall of said tile and on an innerside connecting wall parallel therewith.

Porous ceramic material. E. C. BAYER. Danish 29,386, Feb. 20, 1922. Ferruginous plastic clay is heated above its sintering point, pulverized, mixed with moist plastic clay, molded and burned. (*C. A.*)

Refractories

Alumina and bauxite. R. J. ANDERSON. *Mineral Ind.*, **31,** 8–37(1922).—An article on statistics and changes in technology and uses of alumina for 1922. Diaspore and high alumina clays have nearly taken the place of bauxite for refractories. Large amts. of these clays are being mined in Missouri. Low grade bauxite is used in France for alumina cements. The Everhart process for washing bauxite clays in the presence of small amts. of peptizers has possibilities. Richmond and McDonald obtain a very pure abrasive by melting bauxite in an elec. fur. and reducing impurities with carbon. Quantity production of sillimanite has been started. The use of ZrO_2—10% Al_2O_3 for steel furnaces has been examined. Several new methods for producing K and Al sulphates from feldspars and shales have been proposed. T. N. McV.

Graphite. B. L. MILLER. *Mineral Ind.*, **31,** 347–53(1922).—The graphite industry was almost stagnant in 1922. Wartime stocks have not been exhausted. Prices were lower than in 1922. A British patent contains new features. Natural graphite is purified from silica, alumina, pyrite and mica by intimate mixing with coal, charcoal or coke. The mixt. is elec. heated to approx. 2200°C. The coal unites with impurities which are volatilized and collected. Silica is used for filtering or polishing powder, the SO_3 for mfg. H_2SO_4 and metallic oxides for met. purposes. T. N. McV.

Magnesite. S. H. DOLBEAR. *Mineral Ind.*, **31,** 451–6(1922).—There was an increase of production of 32% in 1922. Imports were $3^1/_2$ times those of 1921. Practically all domestic production came from Calif. and was used in the chem. industries and for mfg. of magnesite cement. Most of the imported mat. came from the Austrian mines. This article gives tables of imports and domestic production. T. N. McV.

Electric furnace phenomena. E. T. MOORE. *Assoc. of Iron and Steel Elec. Engrs.*, **5,** 529–82(1923).—M., in a lengthy paper, discusses the work of the Electric Furnace Committee of the Assoc. of Iron and Steel Elec. Engrs. and presents report of this committee for 1923. Research has been designed to include work along the following lines: (1) a thorough study of the heat losses from elec. furs.; (2) presentation of operating data on fur. electrodes according to the electrode specifs. drawn up by the committee and presented in the 1920 report; (3) an investg. of the merits of dual voltages, and the deleterious effect on the metal, if any, of a relatively high voltage for melting; and (4) investg. of elec.-fur. phenomena. These lines of tests have not been completed with the exception of (3), and work is still in progress. The tests were carried out on a stand. 6-T. Heroult fur. at the works of the Holcomb Steel Co., Syracuse, N. Y., and alloy steels were melted. Much of the data presented are of no interest to ceramists, but certain of the main conclusions arrived at may be summarized as follows: (1) The amt. of unbalancing between phases in an individual fur. is considerable, as shown by oscillograms and graphic meter charts, and the max. difference noted is 340 kw. or 21% of the connected load. This is not of such magnitude as to affect operations. (2) The max.

current values reached during the melting period is 1.1 times normal. (3) Arcs in a fur. set up high frequency disturbances; these are of the order of 5,000 cycles. (4) The power factor was 90% for the melting period and 88% for the refining period, and 89% for the entire heat. (5) The burning out of the back wall in a furnace or the burning of the refractory anywhere within the fur. is a function of the power introduced into the fur. and the distance which the arcs are from such refracs. Burning out of refracs. can be regulated by proper spacing of the electrodes so as to increase the distance of the arcs from the refrac. walls. By closer concn. of the electrodes, the connected capacity can be increased, thus giving a faster melting fur. (6) The limiting capacity of elec. furs. (by which is meant the largest amt. of power that can be introduced into a fur.) varies with the actual size of the fur.; a 25-T. furnace with a connected capacity of 4,500 kva., on a 25-cycle circuit, is about as large as should be installed when melting is done and where only one set of electrodes is used. For hot metal work, a fur. of 40-T. capacity with a connected load of 3,300 kva. is very satisfactory using one set of electrodes of 24-in. diam. In 60-cycle circuits where melting is done, using only one set of electrodes, furs. beyond 15 T. are not recommended, but for hot-metal work a fur. of 40-T. capacity is satisfactory. By using more than one set of electrodes, it is possible to build a fur. of several hundred T. capacity. (7) There seems to be an impression that 60-cycle arcs have less cutting action on the refracs. than 25-cycle arcs, but this cannot be substantiated. (8) It has been claimed that higher temps. can be obtained in 60-cycle furs. than in 25-cycle furs., but this cannot be substantiated. The type and resistance of the current-carrying mat. determines this. (9) With a bath of steel liquid in the fur., the power cannot be safely interrupted for longer than three-quarters of an hr. R. J. A.

Graphites for brass melting crucibles. ANON. *Metal Industry* (New York), **22,** 59(1924).—Discussion of report from Bureau of Mines recommending American graphites. Based on interview with Jonathan Bartley. Gives compositions of alloys used and results of tests by R. T. Stull and L. E. Geyer, denoting that Alabama graphite bonded with American clays gave superior service. Sharp disagreement with this conclusion by two crucible manufacturers led to investigation of research work done by Bureau. Results were obtained only up to 13.1 heats per crucible when a crucible should give from 30–40 heats before being considered commercial. It was found that mats. were assembled in 1918 and crucibles were not ready till December of that year. After the Armistice no effort was made to hasten work and the last of the crucibles were not tested till fall of 1922. During at least part of the period from 1918–1922 good Ceylon or Madagascar graphite could not be obtained and the Alabama graphite was therefore tested against very low grades. Thus, the Bureau results are hardly conclusive and the use of American bond clays is more a matter of indiv. preference and local conditions. R. J. A.

Technical literature on refractories. P. L. M. *Rev. Mat. Constr. Trav. Pub.*, **164,** 93–4B; **165,** 116–8B; **166,** 137–9B; **167,** 152–5B; **168,** 177–9B; **169,** 196–7B; **170,** 215–8B; **171,** 237–9B(1923).—The subject matter and references have been taken mainly from English and American literature. In some cases the references only are given, in others the text and data are also quoted. The information is gathered under the following headings: (1) (*a*) Tests of refrac. (*b*) Slagging tests of refrac. (*c*) Usefulness of standard methods for detg. thermal cond. of refrac. materials. (*d*) Bibliography on thermal condy. of refractories. (2) (*a*) Reversible dilatation of refrac. (*b*) Alumina refrac. (*c*) Magnesite and dolomite refrac. (*d*) Zirconia refrac. (*e*) English (American) methods of testing refrac. products. These cover chem. analysis, porosity, shrinkage, compression strength, fusion tests, coeff. of expansion. (3) (*a*) Chrome refrac. (*b*) Burning life of refrac. (*c*) Amer. specif. standards for glass refrac. L. N.

Natural sillimanite as a glass refractory material. S. ENGLISH. *Jour. Soc. Glass Tech.*, **7** [28], 258(1923).—A discussion. J. G. P.

Graphite in Western Australia. WILSON. *Chem. Eng. & Min. Rev.*, **16,** 101 (1924).—A report on the Mattigallup deposit of graphite by Wilson, Ass't State Mining Engineer. The graphite occurs in flat, shallow, undulating beds of kaolin or clay, in seams varying from 6 to 24 in. wide, which do not appear to be continuous for any great distance. In the No. 1 shaft a bulge seems to have occurred, there being 8 ft. of lode showing. The surface rock consists of hard ironstone laterite in which graphite can be seen in places, and at the bottom of the deeper shafts the country rock, which consists of kaolin, seems to lose its bedded character and may possibly represent the weathered portion of a more or less basic rock. While of low grade and too small for work on a large scale, W. calls attention to the comparatively low grade mines being worked in Canada by dry concn., and by flotation units and electrostatic separators, and recommends some exptl. work on these lines. The Mines Department is now considering giving financial assistance in the development work under the mining development act. O. P. R. O.

The effect of salt coal upon refractory materials. L. M. WILSON. *Colliery Guardian*, **126,** 906–7(1923).—Expts. analogous to those of Clewes and Thompson (cf. *C. A.*, **16** 3821) on the effect of NaCl on SiO_2 are described in which the *effect of NH_4Cl on refrac. materials* was studied. The results show the superiority of high-grade SiO_2 over fire clay for the lining of coke ovens in its resistance to salty coal. The amt. of Al_2O_3 removed from fire clay increased with the temp. 900–10° was a *crit. temp.* below which very little Al_2O_3 was removed and above which a large amt. was removed. No crit. temp. was found for high SiO_2 brick. Fe is also removed by NH_4Cl from bricks at high temps. Comparative expts. with Pt and Si boats showed that free SiO_2 aids the removal of Al_2O_3 from fire clay exposed to NH_4Cl at high temps. Al_2O_3 reacted in some way with the SiO_2 below the m. p. of either, thus confirming the observation of Cobb (cf. *C. A.*, **4,** 1658) of the *interaction of solids at temps. below the m. p. of either.* C. C. D. (*C. A.*)

The silica-brick works of the Consett Iron Co. ANON. *Colliery Guardian*, **126,** 1163–4(1923).—An illustrated description of the Consett Iron Co. brickworks. The products contain approx. 30% tridymite and only a trace of unconverted quartz, insuring *absence of permanent or after-expansion.* Expansion is nearly complete at approx. 600°; none occurs at 1000–1400°; and above 1400° a slight contraction takes place. C. C. D. (*C. A.*)

PATENTS

Graphite crucible. RYUTARO KONISHI. Japan. 41,935, Mar. 8, 1922. The resistance to oxidation and to heat of a graphite crucible is increased by coating the outside first with a mixt. of 70 parts of carborundum, 30 parts of a special porcelain clay and 30 parts of H_2O, and then with a mixt. of 70 parts of a glaze (*e. g.*, made of 45 parts of feldspar, 18 parts of CaO, 10 parts of clay and 27 parts of SiO_2), 30 parts of carborundum and 100 parts of H_2O. (*C. A.*)

Refractory abrasive compositions. L. E. BOURDEAU. Brit. 200,903, April 19, 1922. A mixt. consisting chiefly of bauxite and basalt is fused with smaller proportions of ilmenite, cerite, C, and a flux such as Na fluosilicate. Substance such as emery, corundum, flint, and quartz may also be added. The product may be colored by the addn. of suitable oxides so as to indicate its degree of hardness. (*C. A.*)

Silica bricks. PEASE & PARTNERS, LTD. and J. WILSON. Brit. 193,999, Dec. 8, 1921. Small proportions of china clay and lime are added to Dinas stone, ganister, or other material used in making silica bricks. Preferred proportions are 96% of silica, $2^1/_2$% of china clay and $1^1/_2$% of lime. The china clay and lime are suspended in the water with which the powd. silica is rendered plastic. (*C. A.*)

Dolomite bricks. T. HODSON, J. HODSON, W. HODSON and T. A. HODSON. Brit. 193,576, Dec. 17, 1921. Refractory basic bricks, furnace linings, retorts, etc., are obtained by calcining dolomite, magnesite, or magnesian limestone, adding small quantities (about 15%) of igneous rocks, other than granites and syenites, and in some cases a little basic Fe ore, mixing with H_2O, molding, and firing at 2,000°. Suitable igneous rocks are the peridotites (including diorite and gabbro), the dolerites (including basalts), the serpentines, trachytes, andesites, tachylytes, eurites and rhyolites. If rocks of the last two classes are employed, or if the dolomite contains more than 1% of SiO_2 or 57% of $CaCO_3$, it is necessary to add 3% of basic iron ore, such as titanic iron ore, magnetite, hematite, or gothite. (*C. A.*)

Refractory article and method of making the same. WILLIAM A. HARTY. U. S. 1,473,853, Jan. 22, 1924. A refractory article containing fire clay and fused silica.

Terra Cotta

The unique development of modern chemical stoneware. P. C. KINGSBURY. *Trans. Amer. Inst. Chem. Eng.*, **14,** 275–92(1922).—A very good gen. discussion of the industry is given, with illustrations of products. Process efficiency in much of chemical industry is dependent on varied stoneware shapes adapted to special uses. Most of these have been developed only in the past 20 years. Chemical stoneware is essentially a framework of more or less refractory particles held together by vitrifying clays. Fineness, density and refractoriness of bodies are varied, depending upon the use for the products. The bond clays used must vitrify at the kiln temp., and fuse only at a considerably higher temp., so there will be no softening of shapes in the kiln. It must have high plasticity and strength in the green state, to make possible the production of complicated shapes. Mixtures of various clays are used, which are washed and mixed, and before using are stored in blocks for two years in a satd. atmosphere, which increases the plasticity. Most shapes must be dried very slowly in a carefully controlled atmosphere to prevent deformation in bodies which have from 6–12% linear shrinkage. Burning is carried to about 1300°C, requiring up to 3 weeks in the largest kilns. Stoneware resists the action of all acids but hydrofluoric acid and strong, hot phosphoric acid. Caustic alkali solns. have slight action upon it when hot and concd. Filter presses, large rotary driers, exhaust fans, pumps, condensation coils, complete equipment for muriatic acid plants, etc., are among the newer products made from stoneware.

B. M. L.

Whiteware

Note books of Josiah Wedgwood. B. MOORE AND J. W. MELLOR. *Trans. Ceram. Soc.* (Eng.), **22,** 275–82(1923).—For abstract see **2** [7], 142(1923). H. F. S.

The crazing of English earthenware. A. HEATH. *Trans. Ceram. Soc.* (Eng.), **2,** 213–40(1923).—The common practice of the English earthenware manufacturer has been confined to the use of a certain type of body, which matures at a fairly low biscuit temp., and a glaze which, in general, gives good results at a still lower temp. If the body mats. are controlled by the use of definite chem. and phys. tests, little trouble is experienced, but if, through lack of control, any variation in the compn. of these mats. is ignored, the "balance" of the body with the glaze is upset, and trouble is encountered. The work contd. in this paper expresses the limit of variation in the compn. of a body in relation to crazing and peeling with a given glaze. H. F. S.

Porcelain. S. SCHERTEL. *Mikrokosmos,* **16,** 214–5(1923).—A popular description is given of the use of feldspar, kaolin and quartz in the manuf. of porcelain. Photomicrographs are shown of feldspar and porcelain after heating to different temps. near the m. p. L. W. R. (*C. A.*)

Shock tester for porcelain insulators. W. BUCKSATH. *Elektrotechn. Z.*, **44**, 943–7, 975–80(1923). C. G. F. (*C. A.*)

Equipment and Apparatus

A new electric radiation furnace. A. PAOLINI. *Giorn. Chem. Ind. ed App.*, **5**, 539(1923).—This fur. is designed for operation from 1400–1500°C and is planned for burning of ceramic products. A resistor of graphite (99% C) is used and a refrac. withstanding 2000°C. Radiation channels are used coming into the fur. from the carbon resistor in cone shapes thus giving a greater radiating surface. Various types of terminals are shown and discussed. The furnace operates on 150 kw. A tunnel car type is used also. The furnace is possible for use in metallurgical practice, production of refractories, porcelains, by-product coke, calcination of dolomite, cements, sodium sulphide and sodium aluminate from bauxite. S. S. C.

Notes on the application of pyrometers to ceramic industries. C. E. FOSTER. *Trans. Ceram. Soc.*, **22**, 248–74.—The matter of elec. resistance of the circuit is of fundamental importance. It is necessary that the resistance of the circuit should remain approx. constant with changes in temp. in any part of the circuit, in order that, for any given temp. of the "hot junction," the current flowing in the circuit (and consequently the reading of the indicator) shall be approx. the same as when the instrument was calibrated. A large propn. of the total instrument resistance shall be of mat. which does not change appreciably with change in temp. It is not essential that the total resistance should be high, but only that the propn. of ballast resistance should be high. To make a base metal pyrometer of low total resistance and yet capable of accurate measurement, it is only necessary that the propn. of ballast resistance shall be large enough, and there is no essential need for a high total resistance. The cases where it is necessary to use rare metals in industrial work are only relatively few. Clockwork is the usual device employed for running the recorder mechanism, and there should be a large margin of power to allow the instrument to continue running under adverse conditions. The resistance thermometer, operating by the change in resistance of a coil of fine wire which is put in the place of the "hot junction" of the thermocouple, requires an outside source of current; it does not produce its own e. m. f. It depends upon the balancing of the varying resistance of this coil of wire, known as the "bulb," against other resistances in the instrument. The resistance thermometer should not be used industrially at temps. where distortion is likely to occur, and, therefore, it is not a type of much interest to the ceramic industry. Considerable progress has been made in the application of radiation pyrometers to high temp. measurement. In the case of a pyrometer which operates by the total range of ht. radiations, both short visible and long invisible wave-lengths, known as a "total radiation" instrument, the ht. radiated from the hot body under measurement is concentrated upon some device sensitive to heat, for instance, a very small thermocouple. The instrument then operates in the same manner as an inserted thermocouple. An optical pyrometer is one in which the visible brightness of the hot body is measured or extinguished. In the extinction type, the hot body is viewed through an absorbing medium, the thickness of which is increased until the observer considers that he can no longer see the hot body. Such an instrument requires to be used with the knowledge that the sensibility of the eye depends on the length of time it has been in the dark. The other type depends upon the matching of the brightness of the hot body against that of a source of light carried with the instrument. Here the personal element is much less, exposure of the eye to a bright light will only decrease the closeness of the match and will not alter the position on the temp. scale. One great advantage of the optical pyrometer is that it can be used at much greater working distances, and on much smaller hot bodies, than the total radiation type. H. F. S.

Modern electrical pyrometry. DAVID BROWNLIE. *Chem. Trade Jour.*, **73** [1892], 213–6(1923).—This is a general and not too technical description of the types of elec. pyrometers used, with several applications on boiler practice. The limits of the glass mercurial thermometer are indicated as between 900° and 1000°F for intermittent work, and below that for permanent work. Elec. pyrometry is divided into two classes, thermoelec. and elec. resistant pyrometry. The thermoelec. pyrometers are further classified as base metal and platinum-rhodium pyrometers. The base metal pyrometers are described and several alloys are mentioned as used for the "pointers" or thermoelements. The platinum-rhodium, or Le Chatelier couple, is described and a general theory of the development of current shown. Diagrams and some pictures of English pyrometers are shown, giving the method of indicating or recording the temp. as it affects the elec. current produced. The elec. resistance pyrometer is described and it is just shown for use at distances greater than permissible with the thermoelec. It is useful also at extremely low temperatures, but it is limited at the higher range. Two installations on boilers are described in detail and the advantage of recording instruments is shown. A brief mention is made of the elec. radiation pyrometer, which is a special application of the thermoelec. pyrometer. F. C. F.

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Electrical resistance. S. KATALAIN. Brit. 197,340, May 7, 1923. An elec. resistance mat. which does not fuse or oxidize at high temps. is composed of various ferro alloys, ferro silicon, ferro tungsten, ferro molybdenum, ferro titanium, ferro chromate, etc., mixed with fire clay, magnesite, etc. These are mixed, kneaded and heated to 1500–1600°. W. M. C.

Kilns, Furnaces, Fuels and Combustion

Some new forms of kilns. A. DUCKHAM. *Trans. Ceram. Soc.* (Eng.), **22**, 298–312 (1923).—A kiln of the continuous type, 16 chambers in all, is described. The chambers are arranged in two lines, with wickets on the outside only. There are 4 fire-holes and bags to each chamber, the arrangement of firing being that generally known as semi-gaseous. A. W. D. Central Bag Kiln is discussed. Its advantages are: even heating; bag forms no portion of the kiln proper, can be made of different mat., and can be easily renewed; proper combustion of the heating gases; the brickwork forming the kiln proper is never subjected to the direct action of the heating gases during combustion. The advantages of a tunnel kiln are: saving of labor, fuel, and heating and cooling of the materials. The disadvantages are: mechanical, the great length of the tunnel, the tendency of the htg. gases to rise, and so cause uneven burning. See also *Ceram. Abs.*, **2** [3], 45(1923). H. F. S.

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Brick kiln. YASABURO SAITO. Japan. 42,989, June 30, 1922. This is a parallel ring kiln with two main flues between two burning channels instead of one as usual. Each main flue is connected with the opposite burning channel by small flues which pass under the other. It has a drying chamber on the main flues. Another drying tunnel is constructed around the kiln. Pipes are imbedded in the kiln body over the crown. Hot air produced in them by conduction is utilized in drying bricks by connecting the pipes with the drying chamber and tunnel. (*C. A.*)

Improvement in kiln for burning brick and similar wares. TOKUSABURO SATO. Japan. 42,666, May 20, 1922. The kiln is provided with fire-boxes, each of which has a drop-arch and a channel-shaped wall at its rear. The drop-arch directs the flame produced on the grate downward. The flame then strikes the inverted-channel wall, which is a kind of very low flash wall, situated much nearer to the grate than usual.

The construction keeps the furnace end hot and aids the complete combustion of gases. (*C. A.*)

Geology

The geology of the Bournemouth District. HENRY DEWEY. *Trans. Ceram. Soc.*, **22,** 293–7(1924).—The area dealt with extends from Wareham eastwards to Christchurch, and northward from the Isle of Purbeck to Wimborne. Attention is called to those formations which possess the greatest interest to the English Ceramic Society. H. F. S.

China clay statistics 1919-1921. ANON. *Imperial Mineral Res. Bureau, Min. Ind. Brit. Empire and Foreign Countries*(1924).—China clay statistics for 1919–1921. Introductory note gives different systems used by various countries for computing imports and exports; the annual av. rates of exchange; and states that the British statute ton, 2,240 lb. avdp. (the long ton) is used throughout the rept. The world's production of china clay is given; summary of exports; summary of imports; details of exports and imports for United Kingdom, Canada, India, Czechoslovakia, Denmark, France, Germany, Italy, Sweden, Switzerland and United States are given. The reports conclude with a brief statistical bibliography. O. P. R. O.

Fluorspar statistics, 1919-1921. ANON. *Imperial Mineral Res. Bur., Min. Ind. Brit. Empire and Foreign Countries*(1924).—Different systems used by various countries for computing imports and exports are given in an introductory note, also the average rates of exchange. The long ton (the British statute ton of 2,240 lb.) is used throughout the report. World's production of fluorspar is given; summary of exports and of imports; details of imports and exports for United Kingdom, Canada, Sweden, and the United States are given; also with a list of statistical publications. O. P. R. O.

Kaolin mining, Victoria. ANON. *Chem. Eng. and Mining Rev.* (Melbourne, Victoria), **16,** 100(1923).—Kaolin mining is being actively carried on at Egerton and Gordon. In a crosscut of a new shaft, the deposit of pipe clay is 6 ft. wide, and of very good quality. O. P. R. O.

PATENTS

Pottery. J. E. TAMS. Brit. 198,607, Sept. 16, 1922. A transparent body similar to china, feldspar, or Parian consists of powd. asbestos and powd. frit produced from powd. asbestos and soda fretted in the usual way and ground. China clay, feldspar, or stone may be added. (*C. A.*)

Pottery materials. W. GREEN. Brit. 198,817, March 18, 1922. A ceramic material is made by incorporating hard porcelain ingredients contg. potash, etc., with a sintered irreducible oxide such as pure alumina or zirconia of a high m. p. The compn. is fired at a high temp. to produce a hard tough product having a low elec. condy. and a low porosity. The compn. may consist of alumina, potash, feldspar, china clay, and ground flint. Cores which resist the action of liquid of gaseous Hg may be made from the compn. (*C. A.*)

Fluorite-chillagoe (Victoria). E. C. SAINT-SMITH. *Chem. Eng. and Mining Rev.* (Melbourne, Victoria), **16,** 94(1923).—S. estimates 9,000 T. of high-grade fluorite available at a mining cost of 10 s. per T. with probably a much greater tonnage available below water level. The estimate cost delivered at the port of Cairns is 43s. Analysis of an av. sample from one of the surface outcrops gave 96.74% of calcium fluoride, and 1.12% of calcium carbonate. O. P. R. O.

Preparation of amorphous silica, free from alkali. J. MICHAEL AND CO. Ger. 348,769 (Berlin), (*Oil & Color Trade Jour.*, **65,** 40(1924)).—Precipitated silica, washed

with water or acids, is treated with a metallic salt, especially of the alkaline earths, magnesium or aluminium and then washed again in the usual manner. O. P. R. O.

Note on Quartz from Kragerø, Norway. J. C. JØRGENSEN. *Tidsskrift for kemi og bergvesen*, **3**, 164(1923).—Pre-Cambrian quartzite forming thick benches and occurring in large deposits contains 98–99% SiO_2. The chief impurity is muscovite. The content of Fe is .14–.17%. The annual production from one quarry located on an island has reached 15,000 T. The quartz is used in the manuf. of ferrosilicon and to some extent in ceramics. O. A.

Silica in 1922. F. J. KATZ. U. S. Geol. Survey, *Mineral Resources of U. S., 1922*, Pt. II, 183–6(preprint No. 21, publ. Nov. 27, 1923). E. J. C. (*C. A.*)

Talc and soapstone in 1922. EDWARD SAMPSON. U. S. Geol. Survey, *Mineral Resources of U. S., 1922*, Pt. II, 81–6(preprint No. 13, publ. Oct. 11, 1923). E. J. C. (*C. A.*)

Clay in 1922. JEFFERSON MIDDLETON. U. S. Geol. Survey, *Mineral Resources of U. S., 1922*, Pt. II, 73–80(preprint No. 12, publ. Oct. 10, 1923).—For clay in 1921 see *Ceram. Abs.*, **2** [6], 139(1923). E. J. C. (*C. A.*)

Chemistry and Physics

Borax. A. T. WARD. *Mineral Ind.*, **31**, 80–83(1922).—Borax ($Na_2B_4O_7$) is produced by refining ulexite ($NaCaB_5O_9.8\,H_2O$) and by treating colemanite ($Ca_2B_6O_{11}.5H_2O$) with Na_2CO_3 and Na_2SO_4. Other crude borax minerals of commercial importance are sassolite (from Italy); pandermite (from Asia Minor) and tincal (from Tibet). Borax may be obtained from howlite ($4CaO.5B_2O_3.2SiO_2.5H_2O$). The Oregon borax mineral priceite ($5CaO.6B_2O_3.9H_2O$) is identical with pandermite. Most of boric acid is prepd. by chem. treatment of colemanite. Half of the borax produced in this country or 20,000 metric tons is used in the pottery and enamel industries. All borax produced is from the western part of the U. S. T. N. McV.

Alumina manufactured from clay. H. PEDERSEN. *Tidsskrift for kemi og bergvesen*, **3**, 161–4, 175–8(1923); **4**, 11–17(1924).—The articles describe processes arrived at through extensive exptl. work. The raw mats. were clay, coal and sulphuric acid (chamber acid). The clay is an ordinary brick clay from quaternary deposits and has the following average compn.: SiO_2 55.0, Al_2O_3 16.0, FeO 7.0, MgO 0.7, CaO 1.0, Na_2O 2.5, K_2O 3.5. The process is approx. as follows: (1) The clay is kneaded and mixed with cold chamber acid, the heat of reaction raising the temp. of the mixt. to 150°C whereby SiO_2 is obtained in an amorphous state and is easily filtered. The mixt. is stored for 12 hours. (2) The dissolved clay is leached out systematically three times. The slimes are removed in filter presses. The brine obtained has a sp. gr. 1.35 and contains about 80 g. Al_2O_3 per l. solution. (3) The brine is cooled to about 15°C, this pptg. about $^1/_3$ of the Al_2O_3 as potassium alum formed by the reaction between H_2SO_4 and the Al_2O_3 and K_2O of the clay. The remaining $^2/_3$ of Al_2O_3 is pptd. by adding to the cold, stirred liquid solid K_2SO_4 obtained from previous production. (4) The raw alum is recrystallized with as little water as possible, a pure alum contg. less than 0.01% Fe being obtained. No filtration is necessary. (5) The pure alum is dried in a gas heated rotary kiln. (6) The dried alum is decomposed in a gas heated rotary kiln in slightly reducing atm. The product consists of Al_2O_3 and K_2SO_4, while the H_2SO_4 originally combined with Al_2O_3 escapes as a gas contg. about 6 vol. % SO_2. (7) The decomposed alum is heated with a cold-satd. soln. of K_2SO_4, the contents of K_2SO_4 thereby being obtained in a warm-satd. soln., which on cooling yields crystd. K_2SO_4. Al_2O_3 is removed from the hot soln. by filtration. The cold-satd. K_2SO_4 circulates in the process. (8) Al_2O_3 is dried at 300–400°C for removal of hygroscopic water. (There is

little loss from dusting contrary to what is the case with the hydrate.)—For 1 ton of Al_2O_3 the following amounts of raw mats. are used: Clay 12 tons (at kr. 1.50), coal 2.5 tons (at kr. 15.00), chamber acid 20 tons (at kr. 25.00). A recovery of 400 kg. pure K_2SO_4 (at kr. 0.25) per ton Al_2O_3 is figured on.—In some introductory paragraphs P. compares different methods and criticizes a method suggested by V. M. Goldschmidt for producing Al_2O_3 from labradorite, stating especially that labradorite yields only 19.5% soluble Al_2O_3, while Goldschmidt claims up to about 30%. O. A.

The solubility of alumina minerals in acids. V. M. GOLDSCHMIDT. *Tidsskrift for kemi og bergvesen*, **4**, 9(1924).—A rejoinder to the criticism contd. in the articles of H. Pedersen abstracted above. G. has found that *unaltered* labradorite yields from 20 to 32% Al_2O_3 soluble in HNO_3, while labradorite only partly changed to "saussurite" may be nearly insoluble. Saussurite is a mixt. of zoisite-clinozoisite ($H_2O.4CaO.3Al_2O_3.6SiO_2$) and a lime-soda feldspar rich in soda ($xNa_2O.Al_2O_3.6SiO_2 + yCaO.Al_2O_3.2SiO_2$). G. suggests that the discrepancies may be due to a difference in the labradorite used in the experiments, Pedersen probably having used a somewhat "saussuritized" labradorite. O. A.

Investigations on Norwegian clays. I. J. v. KROGH. *Norges Geol. Undersokelse*, **115**, 1–32(1923).—Some of the more important properties of quaternary clays used in ordinary brick making have been detd. The amt. of H_2O at "normal consistency" varies between 22 and 39%. The drying shrinkage is given with figures between 1 and 11%. The grain size varies widely, the finest clay contg. upwards of 82% of particles smaller than 0.01 mm. and only 0.1% larger than 0.1 mm., while a sandy variety contains 4.6% smaller than 0.01 mm. and 58.3% larger than 0.1 mm. Numerous determinations of softening temperatures gave results between 1050° and 1225°C. Clays fired at 900°C have water absorption between 9.84 and 24.72%, porosity between 21.8 and 37.8%, and sp. gr. between 2.20 and 2.606. O. A.

Investigations on Norwegian clays. II. B. DIETRICHSON. *Norges Geol. Undersokelse*, **116**, 1–58(1923).—A brief outline of the geology of quaternary (marine) clays of southern Norway is given. Samples collected at brick works are described, details of the geology of the places of collection being given in a number of instances. Sketches and photographs accompany the descriptions. O. A.

Investigations on Norwegian clays. III. J. v. KROGH. *Norges Geol. Undersokelse*, **119**, 1–56(1924).—K. describes expts. on quaternary clays and presents the results in tables and diagrams. The limit of satn. (*i. e.*, contents of water in a clay showing incipient flowage) is detd. on 75 samples with results varying from 12.8 to 72.8% (of dry subs.). The max. press. to which clays of varying water contents may be exposed without flowing are considerably higher for fat clays than for lean ones, the difference increasing with decreasing amount of water. The drying shrinkage is detd. on a large number of different clays using of each clay a number of samples with gradually increasing initial water up to the point of flowage. The results calculated as means for 5 groups of fatness are presented in curves where shrinkage is plotted against initial water. A similar series of detns. is made of the water absorption of clays fired at 900°C. A fired clay attains a min. water absorption at a definite initial amt. of water in the wet clay. This amt. varies somewhat in the different groups of fatness, the average being about 24%. An average temp.-porosity curve shows a maximum porosity at about 800°C, all curves declining abruptly at about 1000°C. The molding pressure has only a small influence on the porosity of the fired clay. Curves of crushing strength plotted against temp. of firing show characteristic features. All the curves have secondary maxima at about 500°C and secondary minima at about 700°C. Actual tests seem to show that an industrial production of bricks fired at only 500°C may be possible. Expulsion of water by pressure is facilitated by rapidly increasing pressures or sharp

concussions on the vessel contg. the clay. The plasticity, defined as the difference between the amt. of water in the clay at the limit of satn. and at normal consistency, varies between 5 and 40 for all the varieties examd. The plasticity-temp. curves decline slowly to 400°C, then rapidly to about 500°C, and again slowly to about 900°C; clay fired at this temp. is practically devoid of plasticity. O. A.

The microscopic structure of clays. LÉON BERTRAND. *Recherch. et Invent.*, **4**, 825, 842(1923).—On examn. of 250 secondary French clays B. found an appreciable amt. of mica in only 3 or 4. He concludes that the alkali content usually occurs uncombined, being adsorbed by the clay colloid. He found iron most often present as a hydrated oxide. The free silica particles vary greatly as to size. One clay contained 17% hydrated silica, making it less refractory than a clay with the same amt. of coarse quartz. B. found the clay base itself to be composed of colloids, cryst. kaolinite, as found in kaolin, and cryptocryst. mat., especially abundant in halloysite. Most clays without the addn. of feldspar show granular sillimanite when fired to 1300°, and its formation is almost independent of any fluxes present. Interlacing needles of sillimanite, however, may not develop below 1600°, and a vitreous structure seems necessary for its formation. A high flux content will lower the latter temp., but all fluxes do not act the same. B. contends that the quality of paving brick is largely detd. by the amt. of these needles. P. W. K.

The industrial applications of the electric furnace. E. W. LEWIS. *Engineering* (London), **116**, 257–9(1923).—The charac. of the elec. fur. are const. and regular ht. distribution and accurate automatic control of the temp. The two types of elec. fur. generally used are the induction and arc or modifications of these two types. A. c. is used in indus. applications. The principal uses are: (1) Smelting of iron ores; (2) manuf. of steel; (3) fixation of atmospheric nitrogen and ammonia oxidation; (4) heat treatment in the automobile industry; (5) manuf. of CaC_2; (6) in the annealing of glass, the elec. fur. is rapidly supplanting the fuel-fired fur., due to the accurate control of temp., uniformity of the ht. application and the even distribution of the ht. In the manuf. of fused silica ware silica is heated in an elec. fur. to its m. p. (1800°C). W. E. R.

Determination of melting points. WM. JONES. *Fuels and Furnaces*, **1**, 455–60 (1923).—The detn. of the m. p. or f. p. of a substance is based on the fact that the temp. of the mass remains const. during the transition from the solid to the liquid phase, or vice versa. From a time-temp. curve the m. p. is obtained. From a time-e. m. f. curve for pure substances of known m. p. thermocouples may be calibrated. W. E. R.

The determination of the calorific value of liquid fuels. NELSON HARWOOD. *Engineering* (London), **116**, 396(1923).—By means of an adjustable mercury column acting on a reservoir liquid fuel is delivered to a suitable burner at const. pressure. The fuel is burned at a const. rate in a gas calorimeter of the Junker type. After temp. equil. is attained in the instrument the calorific value is calcd. from the amt. of fuel burned and the quantity of ht. delivered to water circulating through the calorimeter. W. E. R.

The laws of heat transfer. ANON. *Engineering* (London), **116**, 1–3, 69–70, 131–2, 228–30(1923).—Deductions from exptl. data published by G. C. Webster and others. The resist. to the transfer of heat between a tube and a fluid traversing it, in normal turbulent flow, must consist of two terms one of which is independent of the thermal condy. of the fluid while the other term includes this condy. as a factor. The first term is Reynold's convective resist. which is a modification of the proportion $R = v/F$, in which R denotes resist. to transfer of heat, in C. G. S. units, v denotes mean velocity of flow in cm. per sec., and F is the frictional resist. experienced by the fluid per unit area of wall surface in dynes per sq. cm. The second term is the film resist. A con-

siderable fraction of the resist. to heat transfer between a tube and a fluid traversing it is to be ascribed to the existence of a film of the fluid which creeps along the walls in a state of viscous flow. At temperatures above 80°C air contd. in water will be given off, breaking up this film and changing the law of heat transfer. The actual thickness of this film is expressed as a fraction of a mathematically deduced ideal film thickness. The thermal resist. of the film per sq. cm., $R_f = \varphi f_1/c$, in which f_1 denotes the thickness of the ideal film, φ is the ratio of the actual film thickness (f) to the ideal film thickness, and c is the sp. condy. of the fluid. Exptl. evidence indicates that φ is a const. and equal to 0.55. The ratio of the ideal film thickness to the radius of the tube is expressed by the formula $f_1/a = 1 - \sqrt[4]{1 - 8\bar{\mu}v/dF}$ where a denotes the radius of the tube, $\bar{\mu}$ is the mean viscosity of the film, and d denotes the diam. of the pipe. By this equation the film thickness is always a finite quantity however large v or d may be. By substitution, $R_f = 0.55d/2c\,(1 - \sqrt[4]{1 - 8\bar{\mu}v/dF})$. The total resist., R, to the transfer of heat is given by $R = R_r + R_f$. R_r is the modification of the convective resist. formula: $R_r = (1 - \varphi)v/F$. The total resist. then is $R = 0.45v/F + 0.55d/2c(1 - \sqrt[4]{1 - 8\bar{\mu}v/dF})$. When the greatest thickness of the film is less than $^1/_{100}$ of the radius its condy. can be calcd. as if it were flat. In ordinary condenser practice the film may be as much as $^1/_{20}$ of the radius in which case its resist. would be about $2^1/_2\%$ more than if it were flat. $Q = \Delta T/R$, where Q is the heat flow in cal. per sq. cm. per sec. and ΔT is the difference between temp. of the inner surface of the tube and the mean water temp. If R is known under given conditions for a tube of internal diameter d, at corresponding speeds and with the same water and wall temperatures the resist. of a corresponding tube of internal diameter D is found by multiplying the known resist. by D/d. For fluids other than water the formula should read $R = 0.45/s \times v/F + 0.55d/2c\,1 - \sqrt[4]{1 - 8\bar{\mu}v/dF}$), where s is the sp. heat of the fluid traversing the pipe. W. E. R.

The stresses in cylindrical and spherical bodies due to differences of temp. inside and out. CHAS. H. LEES. *Trans. Ceram. Soc.*, **22** [3], 241–7(1923).—A hollow cylinder of circular section, originally at air temp. throughout, is heated till its outside surface is at 1000°C. To find the stresses in the material, its expansion and its elastic constants were given. In all cases considered the stresses in the mat. were due to the rise or fall of the temp. of the mat. from some uniform to some non-uniform distribution, and the values given are for the stresses which exist in the non-uniform condition. H. F. S.

Sodium-aluminium fluoride practically free from silica. HUMANN & TEISLER CHEMISCHE FABRIK DOHNA. Ger. 348,274 (*Oil and Color Trade Jour.*, **65**, 226 (1923)).—The amt. of sodium salt needed for the formation of the double fluoride is gradually added and stirred into the warm reaction liquid. 1 kg. of kaolin, suspended in water, is dissolved in 4 kg. of 40% hydrofluoric acid, the soln. being decanted from the sediment and treated with 620 gr. of carbonate of soda. A ppt. of 1 kg. of the double fluoride (dry substance) is thrown down, while the silicic acid of the kaolin remains in soln. as hydrofluosilicic acid. O. P. R. O.

Electrical conductivity in the zeolites. O. WEIGEL. *Z. Krist. Festband P. v. Groth*, **58**, 183–202(1923).—The purpose of this investigation was to det. whether the H_2O in zeolites is present as mols. or ions; it is shown to exist, in part at least, as ions. By using dry metallic electrodes and a quartz fiber electrometer the condy. of several zeolites was detd. The sp. resistance (cm. ohm) was found to be: stilbite, 2 to 5×10^8; heulandite, 4 to 8×10^{10}; chabazite, 2 to 3×10^8; natrolite, 1.5 to 1.6×10^{12}; apophyllite, 1.7×10^{13}; analcite, 6×10^9. This resistance is low for non-metallic minerals, and is due to the at least partially ionized H_2O content, and not to the cations. This was demonstrated in 2 ways: (1) partial dehydration greatly increased the resistivity of heulandite; (2) substitution of H_2O electrodes notably decreased the resistivity of

several zeolites. The condy. is closely dependent on temp.; for heulandite the sp. resistivity was halved by a rise of 8° in temp. (from 16° to 24°). E. F. H. (*C. A.*)

Specific heats of gases. C. DE LA CONDAMINE. *Chaleur et ind.*, **4**, 64(1923); *J. Soc. Glass Tech.*, **7**, 118; cf. *C. A.*, **17**, 2042.—The sp. heat of gases at const. pressure varies only slightly with the pressure. Thus for air over a temp. range of 27–77° Lussana found a variation of only 0.0015 per 1 atm. change, while at 60° Holborn and Jakob gave a variation of 0.0003 per atm. Lussana found for CO_2 a change of sp. heat at const. pressure of only 0.002 per 1 atm. change, a variation of only 0.9%. Theoretically it could be shown that $dC_p/dp = 2aA/RT_2$, so that the variations of the sp. pressures would be less at higher temps. A table and curves for finding the heat required to raise 1 kg. of steam, air and other gases over varying temp. ranges at varying pressures were given. C. H. H., JR. (*C. A.*)

PATENT

Aluminates. J. KORITSCHONER and F. HANSGIRG. Brit. 199,017, May 30, 1923. Aluminiferous materials such as bauxite are mixed with alk.-earth compds. such as lime and with C in certain proportions and fused in an elec. or other furnace. The product is cooled and powdered, and is leached with a soln. of an alkali such as Na_2CO_3 to obtain alkali aluminate. The leaching may be effected at 100°. The proportion of Al_2O_3 to CaO may be 47.5 to 52.5 and the quantities given in an example are 64.9 parts bauxite, 36.9 parts lime, and 10 parts charcoal. It is stated that metallurgical processes, especially the production of Fe in blast or elec. furnaces, may be carried on so that the slag contains lime and Al_2O_3 in the above propns. so that the Al_2O_3 may be extd. from the slag as above described. (*C. A.*)

General

The distillization of bituminous limestones for the production of mineral oils. LA REDAZIONE. *Giorn. Chem. Ind. ed Applic.*, **5**, 537(1923).—This is a review of the work being carried on by various organizations in Italy for the removing of asphalt oils from limestone. The large deposits occur in Sicily where it is calculated are 320,000,000 T. of rock. A use of the burned rock is being investigated. S. S. C.

Bituminous limestones of Abruzzo and the possible utilization of the distillates. D. MENEGHINI. *Giorn. Chem. Ind. ed Applic.*, **5**, 545(1923).—This rock varies from 5–15% volatiles and about 1–2.5% S. The temperatures of distillation are from 350–375°C. The products formed are ammonia, CO_2, benzol, asphalt oil and tar. Methods of determining S in the oil are discussed and results of per cent of S obtained by various methods are given. The amt. of S in oil varies from 6.8–10.4%. S. S. C.

Non-metallics in 1923. N. B. DAVIS. *Can. Min. Jour.*, **44** [1], 19(1924).—A brief review is given of the developments in production and uses of important non-metallic minerals during the year in Canada. B. M. L.

Saskatchewan's place in Canadian ceramics. W. G. WORCESTER. *Can. Min. Jour.*, **44** [1], 25(1924).—The Univ. of Sask. has included the first and only ceram. engineering course in Canada in its curriculum. Work has been started with Gov't coöperation in the survey of ceramic resources and the testing of clays of Sask. Among the known and tested clays are those suitable for pottery and light ware, for heavy clay products, and for refractories, indicating very diversified clay resources. Pottery, sewer-pipe, building brick, and refractories are now manufactured. Fuel resources are now limited to very large lignite coal deposits and some natural gas. Water supplies and transportation are satisfactory. B. M. L.

Mining in 1923. ANON. *Eng. & Min. Jour.-Press*, **117** [3], 87, 93–7(1924).—Interesting, brief comments are included on the 1923 developments in the production,

imports, exports and prices of asbestos, bauxite, borax, diatomite, feldspar, fluorspar, kaolin, magnesite, mica, silica, talc, etc. B. M. L.

Conservation of heat in power and heating systems. E. R. WEIDLEIN. *Trans. Am. Inst. Chem. Eng.*, **13** [2], 25–42(1921).—The article includes the results obtained up to 1920 at the Mellon Institute in the study of the properties of "85% magnesia" as a heat insulating covering for steam pipes, etc. Good heat insulators usually owe their value essentially to the presence of a large volume of dead air spaces entrapped in a porous mat. "85% magnesia" contains 90% of voids. It is made by mixing 85 parts of pure basic carbonate ($4MgCO_3.Mg(OH)_2.5H_2O$), made by a chem. process from dolomite, with 15% of asbestos fiber, molded to shape, dried 5–6 days, and planed to accurate sizes. The mat. absorbs about 3 times its own wt. of water. Repeated wettings and dryings do not materially affect its properties. Some blocks of the mat. were found to have increased 3% in insulating value after 16–20 years' service. Saturation with oil, however, caused permanent damage to the insulating efficiency. Coverings were used up to 800°F and were in perfect condition after 4 yrs. of service. Ordinarily pipes will rust less rapidly when covered than when bare. Tables and curves are included which show costs of insulation, savings in heat, coal and money, etc. A method is outlined for calcg. the most economical amt. of insulation. B. M. L.

Effective B. t. u. and cost determine value of coal. A. BEMENT. *Power*, **58** [12], 448–50(1923).—The calorimetrical B. t. u. value of coals as determined in a lab. does not always give true practical comparisons; the calorimeter process is perfect whereas practical usage of the coal is often very imperfect. A term known as "effective B. t. u." has been devised. It is by this term that coals should be compared rather than by the lab. B. t. u. A simple method of obtaining the effective B. t. u. is given. Emphasis is laid on the fact that oftentimes the cost of coal at the mines is compared, whereas cost at the point of delivery is what should have been used in the comparison. Examples are given showing that good coal will often pay for itself because less draft is needed, resulting in a lower necessary grate area and possibly fewer boilers. Poor coal means greater losses resulting from less efficient combustion because of coke and coal with the ash and higher stack temps. C. J. H.

Fuel oil and viscosity. M. G. LAUGHAM. *Power*, **58** [11], 423–4(1923).—The purchase of fuel oil was for many years made without any specifs. Later a gravity reading was introduced because it was, in general, an indication of the ease of atomization. With the advent of heavy crudes from the Southwest, gravity readings have become less reliable because of the difficulty of reading them and also because suspended water affects the accuracy. Since the ease of burning is generally dependent upon the fluidity of the oil to the burner, this important characteristic or its reciprocal, viscosity, must be considered. Temp.-viscosity curves show that different fuel oils must be heated over a wide range of temperatures in order to produce similar viscosity characteristics. Also oils of nearly the same gravity should not necessarily be heated to the same temp. in order to be of the same viscosity. Improper viscosity may result in inefficient burner operation. One of the leading burner manufacturers recommends a viscosity of 8° Engler for best operation of his burner. An important point is that the viscosities of certain Mexican oils change under certain conditions of storage depending upon the storage temp. The viscosity does not always change instantly with temp. The capacity of the oil heater depends to a large extent upon the viscosity of the oils passing through it. A great deal could be done to decrease the annual waste if engineers would give closer attention to the phys. characteristics of viscosity. C. J. H.

Oil shale in Tasmania. ANON. *Chem. Eng. and Mining Rev.* (Melbourne, Victoria), **16**, 102(1923).—The shale is finely laminated, brown in color, sectile, tough and resistant to weathering agencies. It is capable of being converted into petroleum prod-

ucts by destructive distillation, samples tested give from 46 to 64 gal. of oil to the ton. In the retorting opern. there are 3 products; crude benzine: kerosene and light lubricating oils; and heavy lubricating oils; this is claimed to be a new departure. The oil shale exists in large quantities, a conservative estimate of the tonnage in 3 leases (totaling 1488 A.), on Mersey River, near Latrobe, has been made at 5,580,000 T.

O. P. R. O.

Australian Chemical Institute. DAVID MASSON. *Chem. Eng. and Mining Rev.* (Melbourne, Victoria), **16,** 103(1923).—At a general meeting held in Sydney, David Masson, first president, announced the incorporation of Australian Chem. Inst. as at Sept. 17, 1923; the first annual meeting to be held in Nov., 1924. O. P. R. O.

Oil sands (South Australia). W. A. HARGREAVES. *Chem. Eng. and Mining Rev.* (Melbourne, Victoria), **16,** 116(1923).—Analysis of the oil film issuing from the bore, at a depth of 1,110 ft., where a 3 ft. belt of oil sand was reported, shows: bitumen 17.6%; mineral oil 74.3%, saponifiable oil 8.1%. O. P. R. O.

The influence of ceramics on the development of the chemical industry. FELIX SINGER. *Chem.-Ztg.*, **47,** 450–1(1923). E. J. C. (*C. A.*)

PATENT

Purifying clay. W. FELDENHEIMER and W. W. PLOWMAN. Brit. 199,795, March 27, 1922. A process for the purification of clay comprizes peptization of the clay in an aq. soln. of caustic alkali, such as NaOH, which contains the hydroxide of an alk.-earth such as Ca, Ba, or Sr, the amt. of reagents added for suspending any given clay being varied according to the hardness of the water used. The soln. of mixed hydrates may be obtained by the interaction of an excess of caustic alkali and an alk.-earth hypochlorite such as bleaching powder in the presence of H_2O. The suspension of clay may be sepd. from the unpeptized impurities, when such are present, and the clay recovered in any desired manner. A sol. hypochlorite may also be present in the liquid for bleaching, deodorizing and sterilizing the clay, in which case a longer period of contact is usually necessary, or the hypochlorite may be added to the suspension after the impurities, if any, have been removed. See *Ceram. Abs.*, **2** [3], 51(1923); *ibid.*, **2** [6], 138; *ibid.*, **2** [8], 190.

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A Monthly Publication Devoted to Proceedings
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of Technical, Scientific and Art Questions and
Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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Vol. 3 April, 1924 No. 4

EDITORIALS

A CERAMIC INSTITUTE

Certified testing of materials and products, and opportunity for determining the most economic methods and processes unbiased by competitive interests are the basic reasons for the increasing demand for a Ceramic Institute. Such an Institute would have to be supported directly by the ceramic manufacturers. It is a cold business proposal stripped of altruism.

The benefits would have to be proven in terms of dollars and cents but with appreciation of the value of looking ahead. A program of investigations that did not anticipate the future needs would be shortsighted and not worthwhile. The present needs must be cared for but to limit an Institute program to these would result in a fluttering of purpose and a temporizing in expediences. To be productive, to prove itself by a dollar and cents standard, a Ceramic Institute must be broad as well as sound in its conception and conduct.

Such an Institute should not overlap in purpose or program any of the existing investigational organizations which ceramic manufacturers are supporting and must continue to support through taxation. The waste which would result from duplication of laboratories and personnel as well as in activities must be avoided. The employment to the full of the existing agencies is sound economy of time, money and human effort.

There is now no non-commercial institution engaged in routine ceramic testing. There is no place where materials and problems can be submitted with surety of being investigated. The Federal and State departments want such an institution and the Ceramic Institute properly organized and equipped would fill this want.

There is now no central pooling agency for technical directing of investigational work. This results in duplication and entails the loss of concerted effort. For example it was proposed at one of the sessions of the White Wares Division of the AMERICAN CERAMIC SOCIETY to initiate an investigation of the sagger problem and of the standardization of feldspar. The U. S. Potters Association has undertaken these but limited only to their own members without the collaboration of the other ceramic groups which are equally concerned industrially and financially. The AMERICAN CERAMIC SOCIETY has not organized to raise funds and to prosecute investigations. It should and does concern itself, however, with finding ways and means of obtaining the fullest possible collaboration in investigations of direct interest to more than one group. This is the reason for its possible interest in a Ceramic Institute.

The success of the joint investigation of kiln fuel economies by the four Heavy Clay Associations shows the value of the several ceramic associations pooling their technical investigations through an institute.

The Mellon Institute, the Federal Bureaus and the Universities offer opportunities for much of this desired collaboration. The services they are rendering should not be duplicated. A more intimate contact of these agencies with the industries should be obtained. The Institute with which this editorial deals would manifold and make more intimate these contacts without in the least decreasing the control over the investigations undertaken and the reports rendered. This Ceramic Institute would provide means for the Universities making similar contacts through fellowships and participation in general investigation programs.

The trade associations should be engaged in technical research of their production problems and in standardization of their product. Promotional sales engineering requires technical research on materials and products, and competition necessitates the highest quality at the lowest cost. That these desiderata are appreciated by ceramic trade associations is shown by the investigations they already are financing in coöperation with the several laboratories and by the proposal by the Common Brick Association of founding a Ceramic Institute.

The Ceramic Institute could be a chartered organization with a directorate elected by the association members. It could employ a Technical Director for full time service and a small staff of part and full time routine laboratory assistants. The Institute would determine the available laboratory and personnel facilities and place with each laboratory the

investigation which it is best fitted to conduct. After placing the investigation, the contact between the financing group and the laboratories would be as direct as it could now possibly be, the Institute through its Technical Director acting in a consultant capacity.

The Ceramic Institute should coördinate its organization and work with that of the AMERICAN CERAMIC SOCIETY using the SOCIETY'S organization for collaborating in research, compilation of data, preparation of standards, investigation of methods, contacting with other investigational societies and institutions; and especially should the Institute employ the editorial, abstracting and bibliography service rendered by the SOCIETY.

The AMERICAN CERAMIC SOCIETY is devoted to promoting the technical welfare of the ceramic industries. It is organized especially for this limited service. In contrast, the trade associations are organized for the promotion of the trade interests of their firm members. It has been the realization of need of technical research in production problems that trade associations have engaged in coöperation with the Federal and institutional laboratories. The SOCIETY was not organized to undertake the financing of investigations. Its function has been to interest trade associations in undertaking technical research of their production problems and the purpose of this editorial is to show that the interested groups can go one step further and coördinate these investigations through a Ceramic Institute without loss of contact and proprietary rights and privileges. This Institute would thus serve a purpose for which no existing organization is qualified to undertake and which would not duplicate, conflict nor alter the present organizations and schemes of coöperation. It would serve as a coördinating agency in ceramic research, reduce duplication, secure collaboration of all groups interested in a given problem and effect economies from these and the several other items of wastage that come from lack of a coördinated program. And not the least important, it would command universal respect for the findings approved by the Ceramic Institute and provide a unit source of information and action.

The AMERICAN CERAMIC SOCIETY would fall short in its obligations to the ceramic industries if it failed to adapt itself to this new scheme of coördinated research.

HAS THE SOCIETY BENEFITED POTTERS?

A prominent pottery owner has expressed regrets that the SOCIETY is not of more benefit to the potters. This criticism, expressed in confidence and without the withdrawal of his corporation and personal membership, is taken as a friendly challenge which the SOCIETY meets frankly and fearlessly. If one, who for years has been and now is a loyal supporter

would question the value of the SOCIETY, surely those potters who have not affiliated and made use of the SOCIETY have no reason for investing in it.

If the benefit of the SOCIETY to potters is not evident, the cause is either that the potters have not been receptive and aware of the agencies through which information has been made available or the SOCIETY is not functioning correctly and making known its activities. We can hold no brief for either the "doubting potter," or the SOCIETY. As it is now constituted and operated, for our concern it gives effective service.

Surely there can be no questioning of the benefits which are possible from a collaboration of ceramists in the searching and recording of information. This is a coöperative research. It is an orderly acquisition of information, an exchanging of the bit which one has found for the total sum recorded by others. It is a coöperative abstracting and recording of the printed records from the world's literature. It is making available to all ceramic industries the things of common interest in each of them.

If there is any value in being informed, surely there is value in this broad coöperative exchanging of information. No one person could possibly accomplish what the members of the SOCIETY collectively are doing. No journal or institution of limited personnel and limited industrial contact could be as effective. No single industrial group working alone could be as broad and thorough. A SOCIETY of ceramists representing all of the ceramic industries is essential to the most effective and the most productive obtaining and proving of that knowledge by which and only by which progress is possible.

It is significant that following the example set by the AMERICAN CERAMIC SOCIETY similar societies have been organized in six other countries. It is significant also that the industries which have enjoyed the greatest progress have engaged most intimately in this same sort of collective searching for knowledge.

The rapid progress made in "potting" in America is creditable to no small extent to the fact that there has been a SOCIETY devoted exclusively and intensively to the finding and proving of scientific facts. This can be proved in specific cases and processes. Such lack of evidence of truth as there may be in this assertion lies in the fact that recorded information is of no value to any individual until it is adapted by him and applied. Differences in ability, and resourcefulness in finding and using facts is a measure of the difference in value to each participant of this organized collecting, abstracting, classifying and proving of specific facts.

There are those like Josiah Wedgewood, to whom it is natural to search for and apply knowledge. He demonstrated that, without school training, and without benefit of trade papers, and without the inspiration and help of organized collaboration of his fellows it is possible to make wonderful

progress. He sought and obtained information and assistance. Like Bell of the telephone, Wedgewood recognized the applicability of various bits of knowledge. It is the ability to sense facts and to make application that distinguishes those who have been the world's greatest inventors and industrialists. This ability will express itself in spite of such handicaps as lack of scientific collaboration.

There are those who obtain very little benefit from school training or from collective research with his fellows. They do not have the capacity to find, to recognize and to use information. But both those most proficient and those least adept in finding and using facts will profit from collaboration with his fellows. If the activities of the AMERICAN CERAMIC SOCIETY have benefited one potter more than another it must be due to the differences in their capacity to recognize and to apply information.

To be consistent in the denial of benefits from the activities of the SOCIETY, one must deny the benefits accruing from ceramic schools, and from the ceramic divisions of the federal bureaus, for which the SOCIETY was directly responsible. To deny these benefits is to deny that progress has been made in manufacturing and in maintenance of quality.

Several potters are participating with profit in the work of the 500 members of the Whiteware Division. They do not question the value to them of its present and potential service. The AMERICAN CERAMIC SOCIETY in general and the Whiteware Division in particular has been and continues to be in form of organization and in activities, very responsive to the most urging demands made on it.

PAPERS AND DISCUSSIONS

THE MEANING OF "KERAMOS" ONCE MORE

By W. A. Oldfather

In the *Keramische Rundschau*, **31** [1–3], 1–2 (1923) (in large part a clear presentation by O. Rasser of present technical usage in Germany), 11–12; 21–2, under the caption "Was versteht man unter Keramik?" Herman Hecht has submitted the[1] "Report of the Committee on Definition of the Term 'Ceramics,'" to a detailed criticism in which he expresses dissent from most of the recommendations of that Committee. At the request of the Editor of this *Journal* I shall reconsider some aspects of the question, because in one very important detail our knowledge of the subject has progressed since the report was made in 1920. Upon the few technical points about processes of manufacture, and the suggestion[2] that a better comprehensive designation would be "Silicate Chemistry," I have, of course, no opinion to express.

Dr. Hecht raises objection to the contention[3] that an established usage offers a measure of justification for the extension of the original meaning of a word, and asks (p. 12), "where and when has the technical world united clay products and glassware under the single designation 'Ceramics?'" (Cf. p. 21.) The answer is United States for some years past, and the substantial evidence for that statement is given on pp. 526–7 of the "Report;" to which we may now also add the twenty countries represented at the Fourth International Conference of Chemistry held at Cambridge, England, June 17–20, 1923.[4] Indeed, one is tempted to go even further, and on the strength of the argument from "the range of material which one finds presented to their readers by the American publications in this field,"[5] to suggest that even in Germany itself, where the need for such a comprehensive designation has brought forth the suggestion "Stone and Earth Products" (*Steine und Erden*), there seems already to be developing a use for the word *keramik* and *keramische* which closely approximates what was until recently the characteristically American one. The *Keramische Rundschau* itself, as a mere glance at its contents will show, contains articles, news, reports, and advertisements of glass manufacture (generally indeed under a separate heading from "Keramik" and "Email") in full measure, obviously as a part of its special field. Not only that, but its full official title confirms this preliminary inference:

[1] *Jour. Amer. Ceram. Soc.*, **3** [7], 526–42 (1920).

[2] *Keram. Rund.*, p. 22.

[3] "Report," p. 542.

[4] (See *Compte Rendu Analytique de la Quatrième Conférence Internationale de la Chimie*, Paris, **1923**, pp. 9, 10, 12.)

[5] "Report," p. 527.

"Keramische Rundschau. Fachzeitschrift für die Porzellan-, Steinzeug- Steingut-, Töpfer-, Glas-, und Email- Industrie." It would seem almost naïve to raise the question, "Where is 'Ceramics' used to include the glass industry?" in discussing a report the very second paragraph of which gives a detailed answer, and in the pages of a journal whose very title is an illustration of the tendency in point.

An important phase of the argument from Greek usage was the contention "that *keramos* and derived forms were not clearly felt by the Greeks to designate the material *per se* (as we speak of 'earthenware')." This was supported by a series of citations from Homer to St. Chrysostom, in which the designations golden, silver, bronze, marble, stone and lead were applied to the word and its derivatives.[1] Dr. Hecht[2] advances now the interesting view that the Greek potters may have called some wares gold, bronze, or silver *keramos* because of the particular color of the glaze. The only fact adduced in support is the occasional use of tiny patches of gilt on a few late vases, but even here there exists nothing that by any stretch even of fancy could be called as a whole "gold keramos," whereas there is no trace in literature or monuments of any silver or bronze *keramos* of the kind postulated, to say nothing of marble, stone, or lead *keramos* (or *keramis*). It is perfectly clear that in the passages cited we do not have to do with earthenware of any kind, but actual metal or stone in the shape of articles that were ordinarily made of earthenware. For example, an earthenware jar with a purely hypothetical bronze glaze, to justify Homer in speaking of a "bronze *keramos*," would have been a very flimsy thing in which to keep the redoubtable god of battles, Ares (Mars), for thirteen months a prisoner; and could any one fancy that the notoriously luxurious and extravagant Cleopatra used only earthenware with an again purely hypothetical gold and silver glaze, instead of actual gold and silver plate, as did not only all ancient princes from Homer's time onwards, but even thousands of well-to-do private citizens?

But after all these are minor points. Dr. Hecht lays most stress on the assertion that *keramos*, whatever its etymology, meant normally "clay" in Greek (p. 2, 11–12, 21), calling attention to the fact that I did not absolutely deny the possibility of this meaning,[2] although I had a shrewd suspicion that it was no more justified by usage than by etymology.[3] It

[1] "Report," pp. 539–40.

[2] *Keram. Rund.*, p. 21.

[3] "Report," p. 537: "*keramos*, a general term designating the product (and perhaps also, although apparently later, if at all), the material of the potter's art." *Op. cit.*, p. 539, n.l.: (After rejecting the best examples given by the lexicons for this meaning of the word) "I do not claim that *keramos* never means 'clay,' for, of course, I have not examined all the thousands of instances of the occurrence of this word, and those that are derived from it, but the cases cited by the lexicons for this meaning are not conclusive, and, in any event, that can scarcely have been the primary meaning."—Anyone

is on this point that the general question has advanced somewhat since the "Report" was published. During 1920 and 1921 A. F. Pauli of the University of Illinois worked upon the lexicography of *keramos* and its derivatives, in part under my general supervision, and presented his results in a dissertation in June, 1921 entitled, "Studies in the Vocabulary of Ancient Greek Ceramics: Keramos and its Derivatives." This dissertation, in part recast so as to make its results more generally understandable, will be published soon, it is hoped, and there the proof will be presented in detail for the contention that *keramos* never means "clay," but only "the baked material of earthenware," "earthenware" itself, some special variety of "earthenware," or some other material in the shape of an article that was ordinarily made of "earthenware." The testimony of the lexicons, accordingly, which in Greek is generally incomplete and antiquated, in this case completely collapses before the unanimous verdict of the etymologists, whose work in contrast with that of the lexicographers is scientific, thorough, and up-to-date, and before an exhaustive examination of all the available evidence drawn from the greatest variety of sources. *Keramos* did not, therefore, either originally, or by derived and extended meaning, designate to the Greeks "clay," but rather primarily "earthenware," or, precisely what its etymology requires, "the burnt stuff,"[1] and therefore an adjective derived from it may, when a widespread technical usage has already developed independently, with propriety be applied to any product "in whose manufacture a change of physical and chemical properties under the influence of high temperatures is required"[2] in which, in other words, "burning" is the characteristic feature of production.

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experienced in lexicographical studies will recognize that in a collection of several score passages containing a term which might be translated by such closely related words as "clay" and "earthenware," there will be a few in which either meaning might make sense. The semantic test is whether there are any passages where a certain meaning is *demanded* in order to make sense. Thus, if in the majority of a large number of sentences *keramos must* mean "earthenware," and with that meaning makes perfectly good sense in all the other instances, while it *never must* mean "clay" but only occasionally *might* mean "clay," where, however, the meaning "earthenware" is just as good, then it is clear that "earthenware" is the only demonstrable meaning for the word.

[1] "Report," p. 539.

[2] "*Ibid.*," p. 540.

FUEL OIL BURNING TO OBTAIN THE HIGHEST TEMPERATURE COMBINED WITH UNIFORM HEAT DISTRIBUTION

By G. Ross

Variants

The many systems of oil burners which exist on the market today make it impossible for Engineers to investigate them individually, and determine which one is most suited to his purpose. In general, burners can be classified as high or low pressure burners, or as burners with a greater or less atomizing effect.

The character of oil used is of first importance, and the results obtained will be widely different between heavy oil, light oil, and all the gradations between these two extremes. The temperature at which oil is fed to the burner is also of great importance.

Objective

It is necessary to combine the above factors in such a way as to produce:

A concentrated long flame
A concentrated short flame
A voluminous long flame
A voluminous short flame

These different flames are used by direct or indirect firing for obtaining

(*a*) A low temperature (500°C)
(*b*) A middle temperature (1000–1200°C)
(*c*) A high temperature (1400–1500°C)

When the desired result is to obtain temperatures up to 1200 degrees by means of direct firing, the matter becomes relatively easy. The object of this discussion is to cover only the most difficult one of the combinations specified, *viz:* to obtain a temperature from 1400° to 1500° and at the same time a uniform distribution of the heat in all parts of large furnaces which are to be heated indirectly.

Discussion

In the case of indirect firing, great resistance is interposed by fire-brick walls or by the walls of a retort to the passage of sufficient calories to secure the high temperature mentioned. For ordinary purposes the best burners are those which give the greatest atomizing of the oil, and the best mixture between oil and air. When this result is secured, the combustion between the two occurs close to the mouth of the burner to secure a long flame with an even distribution of the heat. Such a burner is not suitable for a uniform distribution of heat in a large furnace, using indirect firing and requiring a long flame. Too many calories are developed at the mouth of the burner, resulting in a concentration of heat at that point, and in an impoverishment of the flame beyond that point; which makes it impossible to secure the desired high temperature over the remainder of the furnace. Complete combustion is secured by this atomizing and perfect mixing with air,

but the stream combustion product, has but little more heating value than the gases ordinarily described as waste heat, and with the temperature which resulted from the combustion which just occurred. This temperature is not sufficient to reach 1400° by indirect firing.

One of the most important distinctions between coal firing and firing with oil or cleaned gases, is that in the first case the gases are charged with a multiplicity of particles of ash and unburnt coal. In the second case there are a very few particles of ash or unburnt carbon and the resulting waste heat gases are clear and transparent. The condition of a small number of particles is only true within a short distance of the burner, and the gases at a farther distance have no unburnt particles which can act as a medium for the transportation of the calories. Irrespective of the amount of combustible burnt, the lack of these particles prevents points in the furnace remote from the burners, from reaching the temperature desired. To reach such a temperature some medium is needed for the transportation of the calories from the combustion zone to all the points at which this temperature must be secured.

This is demonstrated by the following experiment:

In a furnace heated by producer gas, from one end, and after reaching the desired temperature throughout the furnace, the gas was closed off, and coke oven gas which had been well cleaned of all mechanically entrained particles, was admitted. The temperature of combustion of this gas was higher than that produced by the producer gas. In spite of this, pyrometric observations taken against the outside and inside of a retort at a distance of one meter from the point where the coke oven gas was admitted, gave the following extraordinary results: As soon as the coke oven gas began to replace the producer gas, the outside temperature of the retort began to fall. The inside temperature remained stationary for some time, and later assumed the same temperature as the outside. This experiment was repeated several times, and it was later found that an excess of coke oven gas had been admitted, and that if this excess were reduced to a minimum, that a certain amount of unburnt carbon resulted, providing a radiant medium, and bringing the temperature back to the same point which was reached by the producer gas. The temperatures involved are approximately 1400° on the outside of the retort, which maintained 1280°C on the inside of the retort. The thickness of the retort wall was 30 mm.

From the above it is apparent that although high atomization and complete air mixing produce highest temperature near the orifice of an oil burner, this combination will not secure the result of uniformly distributing the heat over a large furnace, nor secure the necessary temperature on the inside of a retort. The use of a minimum excess of oil ameliorates to some extent the unfavorable conditions described above. It burns

by slow combustion over the entire distance from the burner to the outlets of the furnace, producing a certain amount of free carbon particles which transport some of the heat from the combustion zone to the more distant parts of the furnace.

This expedient will serve to produce the desired temperature with the ordinary type of burner, but even then the distribution of heat is not uniform over the furnace, being much higher near the burner, and much lower near the waste gas outlets.

To secure this latter result it is necessary that the burner does not atomize the oil, but rather throw it into the furnace in particles comparatively small, but still of sufficient size so that complete combustion does not take place until the entire length of the furnace has been passed. This system of combustion is only possible when the temperature of the furnace is very high (about 1400°), as otherwise rapid and complete combustion would not be secured. Theoretically, the mixture of air and unburnt oil must continue until the most remote parts of fire-brick wall or retorts are reached, in order that these latter points will have a continuous influx of calories. To have the heat distribution uniform and at the correct temperature, the burner must supply sufficient perfect combustion near its orifice and produce the highest temperature desired, and there must be a sufficient excess of unburnt oil and air to transport this temperature to the farthest points of the furnace. These unburnt particles of oil and air, must impinge on the farthest retort and burn at that point to complete combustion. These particles must still be fine enough to assure complete gasification and rapid burning.

Conditions will be greatly dependent on the quality of the oil, and its temperature as it enters the burner. If the oil is too light, it will be too easily volatilized and will be decomposed too soon in high temperatured furnaces before being able to complete the trajectory to the end of the furnace. If the oil is too cold, it will not permit a rapid combustion, nor will the particles produced by the burner be of sufficiently fine size; while at the same time it will prevent the obtaining of the high initial temperature desired near the mouth of the burner.

To secure the conditions desired as outlined, the highest temperature must be developed near the burner mouth, and the stream of unburnt and waste products must carry in suspension sufficient particles of oil and air, so that their gradual combustion will produce heat and carbon particles over the entire distance until each part of the furnace has been reached. The specific gravity of the oil is limited on the one hand by the fact that higher gravity oils will volatilize too quickly; and on the other hand that the heavier oils will form particles so large that they will not burn quickly enough. The correct oil will form particles which will be large enough to last until the remote points of the furnace are reached,

but which at that point will be entirely consumed. These particles, at the same time, act as transmission agents for the excess calories which are produced near the burner and carry them to the more remote points.

It is evident that these heavy particles in the stream of oil and air have a natural tendency to drop to the bottom of the furnace, leaving the stream too poor in hydrocarbons as the farthest end of the furnace is reached. To overcome this factor, it is necessary to give the oil and air a strong mechanical impulse at the burner, which will insure the travel of these particles to the farthest points of the furnace before allowing them to drop.

An important distinction between oil and gas firing is that the number of calories produced from oil or other high calory fuels in a given unit of time is much larger than that produced by producer gas. This necessitates careful designing near the orifice of the burner to provide the correct combustion space that may be required by these different fuels.

The object of this article is to present some phases of this important question to the attention of the different engineers and metallurgists who have experimented along these lines, and to invite their discussion.

METALLURGICAL ENGINEER
GENERAL MANAGER, SALTILLO, MEXICO

REFRACTORIES QUESTION BOX

E. E. AYARS, EDITOR

I. What effect does 2% or more of titanium oxide have on fire-clay refractories?

Discussion

It lowers the fusion point slightly. A value of $^1/_2$ cone per 1 % has been suggested when the clay has a composition similar to that of kaolinite. However, most fire clays contain 2% of titania, the amount present usually varying with their alumina content. This is a fortunate condition as the more aluminous clays are better able to carry the additional burden. Generally speaking the better clays high in silica carry about 1%, the "normal" clays about 2%, and the highly aluminous clays 3%. It is quite probable that the fluxing power of titania is less than $^1/_2$ cone per 1% when present in the small amounts found in fire clay—a rough value of $^1/_4$ cone per 1% might be more appropriate. It is difficult to lay down an iron clad rule because of the different forms in which it may be present and the other characteristics of the clay.—RAYMOND M. HOWE, Kier Fire Brick Co., Pittsburgh, Pa.

The following discussion is taken from "British Clays, Shales and Sands."—A. B. SEARLE.

Titanium compounds occur more frequently in clays than is commonly supposed, though only in small quantities (under 2% TiO_2) and in the ordi-

nary methods of analysis it is included in the figures for alumina. Titanium compounds occur chiefly as rutile (TiO_2), ilmenite ($TiFeO_3$) and titanite ($CaTiO_5$) and act as somewhat powerful fluxes; hence clays which are required to be highly refractory should not contain more than 2%. Several investigators have independently examined the effects of titanium oxide on china clay and on artificial mixtures of alumina and silica. Their results show that within the limits in which this substance usually occurs in clays, the reduction in refractoriness is less than 40°C and is therefore negligible if less than 2% of titanium oxide is present. Ten per cent of this oxide lowers the softening point of kaolin about 100°C, but on fire clays richer in silica it has less effect.

II. What is the effect of 2% or more of titanium oxide in refractories, upon their resistance to alkaline fluxes?

Discussion

The tests made by the writer were parts of a general study of the resistance of refractories to alkaline fluxes. They were made by preparing a glass of arbitrary but constant composition (using sodium carbonate and sand only) so selected that it could be melted to a thin fluid at heats obtainable in the laboratory, and consequently more alkaline than commercial glasses. Test pieces of the refractories were made into roughly cubic form. A quantity of the glass mentioned above, bearing a definite relation by weight to the test piece of refractory, was melted in a platinum crucible. The test piece was dropped into the melted glass, and allowed to remain there, covered, for one-half hour. The mass was then poured out, the glass adhering to the test piece was dissolved away, and the cleaned piece ignited and weighed. The loss in weight as compared with the original condition was taken as an index of the resistance of the refractory.

In these tests the action of the flux was confined to the surfaces of the test pieces. There was no indication that the flux penetrated the entire mass and selectively removed the less refractory components. It was recognized that this highly accelerated test might lead to faulty conclusions in deciding as to the best ratio of silica to alumina in the refractory but it was thought that by adding increased amounts of titanium oxide to a known mixture of clays that some idea of its effect might be gained. In this way the following results were obtained:

Loss from test piece made from clays containing 2–3% TiO_2	14%
Loss after adding to same mixture 10% TiO_2	27
Loss after adding to same mixture 50% TiO_2	50

Although these tests should be repeated and greatly extended to reach a right judgment as to the effect of titanium oxide, they are sufficient to create in the mind of the writer the impression that this material decreases rather than increases the resistance of refractories toward alkaline fluxes.

It may be added that similar tests with zirconia led to similar conclusions.—J. D. CARTER, Phila. Quartz Company, Philadelphia, Pa.

(NOTE—Further discussion of the above question is solicited.)

III. What is the best type of brick to use in the side walls of air furnaces?

Discussion In contributing to a discussion on the character of refractories required for service in air furnace side walls little can be added to what the writer has already said elsewhere from time to time.[1]

A very casual inspection of an air furnace at the end of a campaign discloses the fact that the greatest destruction has taken place at the slag line, until the wall has become so thin that the better preserved brick, higher up, must be removed and the lining rebuilt to prevent the wall tipping over.

Since the walls near the roof are hotter than at the slag line, it is evident that brick as now made resist temperature better than chemical action. Spalling in side walls, though not unknown, is rather unusual.

The point of attack for the side wall problem is thus to produce a chemically resistant brick. Chemical resistance, for a given material, may be increased by decreasing slag penetration by making a denser brick. Fine grinding, hard pressing, high firing temperature, and a correct grading of fine and coarse material are means in this direction.

Theoretically, it is possible to imagine a refractory less likely to combine chemically with the slag constituents. The problem would then become one of making an artificial mineral to order rather than of using natural clays.

In the malleable furnace the chemical problem is complicated by the changes in composition of a slag during melting. The first material formed is nearly pure molten Fe_3O_4. This becomes reduced promptly to FeO, and combines with SiO_2 from the brick, sand bottom, and the oxidation of Si in the metal to a final composition approximating

FeO	29.0
Fe_2O_3	1.0
MnO	5.0
SiO_2	51.0
Al_2O_3	14.0
	100.0

We have thus at various stages of the same heat slags ranging from the most basic to the most acid of open hearth practice. Fortunately, during the larger part of a heat the slag remains of the last given analysis. It

[1] Schwartz and Gorton, "The Requirements of Fire Brick Suited to Malleable Practice," *Jour. Amer. Ceram. Soc.*, **6** [10], 1094 (1923).

may be well, however, that most of the actual damage is done by the slag while basic. The entire problem would seem to possess great interest for the ceramist.—H. A. SCHWARTZ, Nat. Malleable Castings Company, Cleveland, Ohio.

Fire brick to be used in the side walls of air furnaces in the malleable iron industry must withstand high temperatures, sudden changes of temperature, and the chemical and physical action of a basic slag.

Some companies line their furnaces with coarse grained open textured brick, while others use a very fine, hard burned brick. It is probable that the best type for general use in this connection is a "happy medium" between these two extremes. Brick of open texture will naturally absorb considerable slag and this may eventually cause failure, but usually such brick, if of the proper chemical composition, glaze over and absorb very little, if any, additional slag. Hard brick will not readily absorb slag but are sensitive to thermal shock.

Siliceous clay brick fail quickly in air furnaces from spalling and from the chemical action of the slag.

The type of brick that has given exceptionally good results in the sidewalls of air furnaces has a chemical composition approximating that of kaolinite, has a fusion point of cone 32, low slag absorption, porosity of about 20%, medium grind and a light burn.—C. E. BALES, Louisville Fire Brick Works, Louisville, Ky.

IV. Does the use of powdered coal decrease the life of fire brick in malleable iron furnaces?

When powdered coal was first introduced for melting in malleable iron furnaces excellent results were obtained from the refractory lining, but later, some foundries experienced considerable trouble from slag action and flame erosion. At present, malleable iron experts are of the opinion that the brick give the same service in powdered coal fired furnaces as they do in hand-fired furnaces of the same capacity.[1]—C. E. BALES, Louisville Fire Brick Works.

In discussing the requirements of refractories for any particular service one must not lose sight of the fact that each furnace installation is a distinct problem in itself. The matter of combustion chamber design enters into the question of hand firing, powdered coal or oil burning and the service of the refractories in various parts of the furnace will be more or less satisfactory, depending on the amount of furnace experience built into the furnace.

Without doubt the use of powdered coal enables the melter to push the furnace much faster than is possible with hand firing, and the same

[1] Schurecht and Douda, "The Behaviour of Fire Brick in Malleable Iron Furnace Bungs," *Jour. Amer. Ceram. Soc.*, **6** [12], 1232 (1923).

thing applies to the use of oil. With proper combustion chamber design the service of side wall and bung brick should be as good with powdered fuel as with solid.

The same refractory will not always serve in either case and the selection of the brick to use must be made from a practical test.—ED.

ACTIVITIES OF THE SOCIETY

PRESIDENT'S PAGE

By Robert D. Landrum

A conception of the real interest of the industries in general in what the Ceramic Society is doing is reflected in the space given to our Atlantic City Meeting by the various trade journals. The March issue of the *Ceramic Industry* uses eighteen pages and nineteen cuts, a very well-written article covering in detail the general session as well as the sessions of each of the seven industrial divisions. They say that this meeting was the "biggest and best Convention that this august body has every had." The *Chemical & Metallurgical Engineering* in their Feb. 11th and Feb. 18th issues use nine pages and nine illustrations, reporting especially in detail the general session and the sessions of the Refractories, Enamel and the Glass Divisions. The *Glass Industry* devotes four and one-half pages and uses twelve illustrations in reporting our meeting, and are especially to be commended for their excellent account of Glass Division Meetings. The March number of the *Brick & Clay Record* covers very completely the Convention activities of the Heavy Clay Products, the Refractories, the White Ware and the Terra Cotta Divisions, using six pages and three cuts; and the *Enamelist* in two pages reports the Enamel Division Meeting. The *Clay Worker*, the *Glass Budget*, the *Glass Worker*, the *China, Glass and Lamps* and the *Pottery Glass and Brass Salesman* were liberal in the space given to the report of this Convention.

A comment of *Chemical & Metallurgical Engineering* in reporting our Convention is especially to the point, for it emphasizes an admirable quality typical of our Society, a quality that is fundamental in our success. The comment is as follows:

"From the climatic point of view, Monday, February 4th was perfect and the fact that nearly three hundred resisted the natural temptation to join the throng on the board walk speaks well for the excellence of the program and is an indication of the genuine interest in the activities of the industry that permeates this organization."

As a matter of fact, practically every member at any one of our meetings finds that if he misses a single hour, he has missed something of real definite value in his work. Even more attractive than the opportunity to bask in the sunshine of a Spring day in February and to fill our lungs with the unbreathed air, fresh from over the Atlantic Ocean was the opportunity to revel in the discussion of our every-day problems and to drink to our full the inspiration from papers by resourceful fellow workers who had put in black and white some of the things we have long wanted to know.

Inspiring research work along the right lines is an important work. This is being handled as effectively by the service committees as can be expected under the conditions. The immediate and most urgent task of the Board is to show those who are being benefited just how they can make the work of these committees more effective. Our field of usefulness and the expectations of the service have increased faster than our income will allow. There are many things we should do which we cannot without a larger income. The Society is solvent and is now operating within its income but our activities are far from what they should be.

Our funds come from three sources—dues from the members, both personal and corporation; payments we receive from our advertisements in the *Journal;* and the receipts from the sale of our publications. The Board of Trustees considered a long time before increasing the dues of the members from $7.50 to the constitutional limit of $10.00.

It would be better to have every corporation an interested member at $25.00 a year rather than a fewer number at a larger fee. The larger number of members has a double result; gives us more capital to work with and adds another worker. Both of these increase our ability to serve. Any efforts we make to increase our list of cor-

poration members will assist in making the industries as a whole realize that our activities have a real value from the dollar standpoint.

In just the same way, when we obtain a new advertiser, we are doing him a distinct service, for our *Journal* goes to a selected list of men to whom he can for a very small sum of money tell his story each month and reach them when they are in a receptive mood. Our members and the readers of the *Journal* are the men who make the final decision regarding materials and equipment to be used.

You, who are reading this page, are the fellows who can make our financial problems easy. You know a man in an organization already a corporation member who should be a personal member. You know a corporation—perhaps it is your own—that is benefiting from the work of our SOCIETY and yet is not a corporation member. Every day you are buying materials from companies not represented on our advertising pages. Just think what it would mean to the SOCIETY if everyone who reads this page would write today to one man who should be a personal member, to one corporation that should be a member, and to one supplier of materials who should be an advertiser. Here are the fruits of work done in the securing of new members last month.

MEMBERSHIP WORKER'S RECORD

	Personal		Personal
Alfred O. Ashman	1	J. W. Mellor	1
A. U. Cote	2	R. C. Rahn	1
F. W. Donahoe	2	Frank S. Roberts	2
R. F. Ferguson	2	W. F. Rochow	1
Howells Fretchett	1	John Sawyer	2
C. B. Harrop	1	Alexander Silverman	1
Charles J. Hudson	1	Office	9
Eugene J. Hysell	1		—
R. D. Landrum	1	Total	29

The Roster Continues to Rise

	Personal	Corporation	Totals
Net Record Jan. 15	1990	296	2286
Acquisition up to Feb. 15	41	8	49
Acquisition up to Mar. 14	29	0	29
Gross Totals March 14	2060	304	2364
Withdrawals	68	5	73
Net Roster Mar. 14	1992	299	2291

NEW MEMBERS RECEIVED FROM FEBRUARY 15 TO MARCH 15

PERSONAL

Andrews, Andrew Irving, Graduate Student, U. S. Bureau of Mines, Lord Hall, Ohio State University, Columbus, Ohio.

Aregood, Joseph M., Foreman Molding Dep't, Vitrefrax Company, 1317 E. 61st St., Los Angeles, California.

Buit, Theodore, Enameling Dep't, Alaska Refrigerator Co., 36 Rathburn St., Muskegon, Mich.

Carter, C. C., Sup't Buckeye Tile Co., Chillicothe, Ohio.
Cochran, A. D., Salesman Clay Working Machinery, Bonnot Co., Careton, Ohio.
Devereux, Percy Stewart, Works Mgr., The British Abrasive Wheel Co., Ltd., Tinsley, Sheffield, England.
Duggan, Adele Ida, Occupational Therapist, U. S. Veteran's Hospital No. 16, Oteen, N. Carolina.
Helmer, Charles M., General Mgr. Hall and Sons, Inc., 69 Tonawand St., Buffalo, New York.
Holland, Henry Donald, Engineer Crooksville Shale Brick Co., Crooksville, Ontario.
Howe, W. L., Research Assistant, Norton Co., 16 Greendale Ave., Worcester, Mass.
Kane, Richard S., Draftsman, C. B. Harrop, 1591 N. Fourth St., Columbus, Ohio.
Lewis, Nathan E., Engineer of Babcock & Wilcox Co., 85 Liberty St., New York City.
Mauser, H. W., Jr., Engineer, Royal Delftware Manufactory, 20 Julianalaan, Delft, Holland.
McLaughlin, N. H., Sec'y Alsey Brick and Tile Co., Alsey, Illinois.
Myers, E. F., President, The Ironton Fire Brick Co., Ironton, Ohio.
Miller, William B., Ceramic Section of the Research Dept., N. J. Zinc Co., 462 Lafayette Ave., Palmerton, Pa.
New, Ryland H., President, The Hamilton & Toronto Sewer Pipe Co., Ltd., Hamilton, Ontario, Canada.
Poxon, G. J., Pottery Manufacturer, 2300 E. 52nd St., Los Angeles, Calif.
Remsen, John N., Assistant Gen. Sales Mgr., United Alloy Steel Corp., Canton, Ohio.
Robertson, Foster, Junior Fellow, Mellon Institute, Pittsburgh, Pa.
Rodgers, Henry P., Partner, Rodgers and Reitz, 15 E. Fayette St., Baltimore, Md.
Roefer, Chas. M., Ceramist, Federal Clay Products, Mineral City, Ohio.
Roy, William, Sup't, Crooksville Shale Brick Co., Crooksville, Ont., Canada.
Schwall, Harry Edwin, Aid to Sup't, Southern Potteries, Inc., 605 Ohio Ave. Erwin, Tenn.
Sheppard, F. W., Harbison-Walker Refractories Co., Brown Marx Bldg., Birmingham, Alabama.
Spence, Hugh S., Mining Engineer, Mines Branch, Dep't. of Mines, Ottawa, Ontario, Canada.
Thorman, Floyd M., Laboratory Supervisor, United States Gypsum Co., Oakfield, New York.
West, Charles, President, Glass Manufacturing, Grapeville, Pa.
Willmer, Heinrich, Heat Efficiency Expert, Cologne Nippes, Germany.

NEW ENGLAND SECTION MEETING

The first meeting of the year for the New England Section of the AMERICAN CERAMIC SOCIETY was held at the Boston City Club on March 8th with the following members and friends present.

J. R. Fuller, Hygrade Lamp Company, Salem, Mass.
R. Booth, General Electric Co., Lynn, Mass.
R. P. Newhall, General Electric Co., Lynn, Mass.
H. L. Young, Bristol Company, Old So. Bldg., Boston, Mass.
J. F. Indordohnen, Bristol Company, Old So. Bldg., Boston, Mass.
W. L. Howe, Norton Company, Worcester, Mass.
G. L. Nordin, Superior Corundum Wheel Co., Waltham, Mass.

Wm. Pettigrew, Norton Company, Worcester Mass.
Glenn D. Williams, Norton Company, Worcester, Mass.
Arthur T. Malm, Norton Company, Worcester, Mass.
Charles J. Hudson, Norton Company, Worcester, Mass.
Gustaf A. Hiding, Norton Company, Worcester, Mass.
H. L. Watson, General Electric Co, Lynn, Mass.
O. C. DuSossoit, Taylor Instrument Co., Boston, Mass.
C. B. Tilton, Cortland Grinding Wheel Co., Chester, Mass.
Leon B. Bassett, Baxter D. Whitney & Son, Winchendon, Mass.
Elliot D. May, Baxter D. Whitney & Son, Winchendon, Mass.
Prof. Gordon B. Wilkes, Mass. Inst. of Tech., Cambridge, Mass.
Prof. Charles L. Norton, Mass. Inst. of Tech., Cambridge, Mass.
Dr. S. W. Stratton, Mass. Inst. of Tech., Cambridge, Mass.
R. Richardson, Mass. Inst. of Tech., Cambridge, Mass.
Irving B. Loud, Norton Company, Worcester, Mass.
Edwin G. Chaffin, Norton Company, Worcester, Mass.
George Henderson, Dorchester Pottery Wks., Boston, Mass.
R. M. Farnsworth, Lancaster, Mass.
M. F. Cunningham, Waltham Grinding Wheel Co., Waltham, Mass.
C. H. Lawson, Waltham Grinding Wheel Co., Waltham, Mass.
Albert A. Klein, Norton Company, Worcester, Mass.
Arthur E. Baggs, Marblehead Potteries, Marblehead, Mass.

At the election of officers it was voted that the same members serve again for 1924.

The speakers for the evening were, Dr. S. W. Stratton and Prof. Charles L. Norton, and Prof. Gordon B. Wilkes of the Massachusetts Institute of Technology.

They spoke on "The Proposed Development of Ceramics" and "Ceramic Research at the Technology."

A general discussion followed.

Tentative plans were suggested on forming a committee representative of the Ceramic Industries of New England to meet with Prof. Norton and his associates to formulate means whereby the Technology could better coöperate with the New England Ceramic Industries and help them with their problems.

The suggestions met with a great deal of enthusiasm and further work will be done along this line.

At the close of the discussion a rising vote of thanks was extended to Dr. Stratton, Prof. Norton and Prof. Wilkes and the meeting adjourned.

C. H. LAWSON, *Secretary-Treasurer*

FIRST CERAMIC MEETING[1]

Southern California Section of American Ceramic Society Discusses Future of Industry

A representative gathering of the heads of many important clayworking, refractories and other ceramic industries of Los Angeles and vicinity met at the Hotel Clark during the week, the occasion being the first regular meeting of the newly organized Southern California section of the AMERICAN CERAMIC SOCIETY, a national organization devoted to the advancement of the ceramic industry.

[1] *Los Angeles Sunday Times*, Mar. 2, 1924.

The officers of the local section are: A. Malinovsky, president; G. Ray Boggs, vice-president; Thomas S. Curtis, secretary-treasurer. Its membership is made up of the technical and executive heads of departments of practically every important ceramic manufacturing concern in the Southwest.

Interspersed between the various discussions of economic and technical interest, were musical numbers rendered by the young daughter of the president, Miss Olga Malinovsky, pianist, with violin by Master Charles Malinovsky. B. C. Berg, of the Schurs Oil Burner Company, sang.

Among the most welcome speakers of the evening was Prof. Hewitt Wilson, head of the department of engineering of the University of Washington. After showing the gathering that Seattle can boast and boast quite as enthusiastically as Los Angeles, Prof. Wilson gave an intensely interesting account of the work at the University, which work has had the collaboration of the United States Bureau of Mines through the Northwest Experiment Station. The first, and probably the most important work accomplished to date, has been a thorough survey of available raw materials, of which there appears to be an inexhaustible supply and a very considerable variety. It is Wilson's opinion, founded on this investigation, that the Northwest will some day be as independent from the ceramic standpoint as is Los Angeles, although much development work and a huge investment must needs be made before that section can hope to approach the importance of the Southwest in this big industry.

An intimation of the value of the AMERICAN CERAMIC SOCIETY in its relation to the economic development of the high temperature industries of the Southwest, was manifest in an informal talk by Thomas S. Curtis, president of the Vitrefrax Company of Los Angeles. This Company, a little more than three years ago, started the manufacture of super-refractories in a small plant in the Vernon district, specializing in the most difficult problems of the industry. From that small beginning, the Vitrefrax Company has grown to hold an unparalleled place in the refractories field, with an investment of nearly three-quarters of a million dollars in a modern steel and concrete plant, conceded by eastern visitors to be the finest and most unique refractories institution in the world. The business is nation-wide, approximately 70% of the product being shipped to eastern steel mills, copper refineries and electric furnace plants.

An appeal by Curtis, to the members of the fire-brick industry present brought to light a curious misapplication of technical data, as applied to the sales of fire brick. It appears that for many years it has been the custom to describe a fire-brick as being able to "stand so many degrees of temperature." The salesman having a high grade brick, refers to his brick as being able to stand 3200°F, for instance. This is commonly accepted as the melting point of the brick, and leads one to believe that the brick is satisfactory for service up to that point.

Mr. Curtis brought out the point that this is misleading unscientific and occasionally dangerous, for the reason that a softening takes place in all firebrick in some cases a thousand degrees below the actual melting point. It is the softening or deformation point that determines the suitability of the brick for service in specific cases. His plea was for all fire-brick makers to get together and agree to a specification or description of the characteristics of a fire brick that would give the customer and especially the engineer an inkling of the adaptability of the brick in his own problems.

To accomplish this, a new set of standards would have to be used. The melting point could be ignored altogether, and the temperature at which warping occurs, under a known load and shear stress, would be used as the indicator. The practical value of this suggestion has been recognized by customers of the Vitrefrax company all over the country, the appeal being unique in that it serves to give the customer an idea of the practical or utilitarian value of the brick in service.

The discussion which resulted from this suggestion was right to the point, and it showed the intense interest of a great majority of members who were not firebrick manufacturers but fire-brick users.

Other speakers on the program were Samuel Geijsbeek, who helped to organize the first section of the AMERICAN CERAMIC SOCIETY many years ago in the East; Mr. Steinhoff, of the *Brick and Clay Record*, and *Ceramic Industry*, two leading journals of the industry; Mr. Weber, of the Russell tunnel kiln organization of St. Louis; and Mr. Jackson, of the Empire China Company of Burbank. Mr. Jackson spoke on the availability and suitability of white burning clays and other ingredients of the raw mix in white chinaware.

Plans for the summer meeting of the SOCIETY to be held in Los Angeles were discussed by the presiding chairman, F. B. Ortman, of Tropico Potteries, Inc. A program has been arranged for the visiting members from the East, and it is estimated that more than one hundred visitors with their wives will come to Los Angeles on this occasion. Many plant visits have been planned, and it is believed that this influx of the heads of important ceramic plants of the eastern section may serve to stimulate further the development of our already full-fledged ceramic industry here in the Southwest.

ST. LOUIS LOCAL SECTION MEETING[1]

On March 18, 1924 the St. Louis Local Section of the AMERICAN CERAMIC SOCIETY held their quarterly meeting at the American Annex Hotel. "Oxygen—the Wonder Worker" was the title of an interesting motion picture illustrating how liquid air is made and why oxygen can be extracted from the air; how acetylene is made, and how gases are used by modern industry to effect the economies of oxyacetylene welding and cutting. This picture was produced by the United States Bureau of Mines in co-operation with the Air Reduction Sales Company. G. E. Harcke, industrial engineer for the latter Company, gave a talk on the same subject.

A special feature of the meeting was an actual demonstration of machine flame-cutting devices.

Reports by various members who attended the Atlantic City Meeting were given and a discussion of the proposed Ceramic Department at the University of Missouri was given.

PITTSBURGH LOCAL SECTION[2]

Members of the Pittsburgh Local Section of the SOCIETY held a meeting on the evening of March 20 in the Auditorium of the Pittsburgh Section of the U. S. Bureau of Mines. The address of the evening was given by Dr. Albert Sauver, Professor of Metallurgy of Harvard University. His subject was "The Behavior of Steel under the Action of Heat."

DENVER NOW IN SUMMER MEETING SCHEDULE

Attractive Addition Made to Itinerary

Daily increasing interest in the plans for the Summer Meeting tour to the western coast of the United States is being manifested by the members of the AMERICAN CERAMIC SOCIETY. The latest announcement that Denver will be visited on the return trip

[1] L. C. Hewitt, Secretary.

[2] H. G. Schurecht, Secretary.

with the Denver ceramists as cordial hosts has been greeted with enthusiasm. This latest addition to the itinerary has been made with *no* additional railroad fare.

The ceramic party will leave Los Angeles for Grand Canyon and after a visit there will go directly to Denver for plant and social visits.

The itinerary for the four weeks' trip is as follows:

Leave Chicago	July 21
Spokane	July 25
Seattle	July 26–28
Lincoln	July 30
San Francisco	July 31–August 2
Yosemite Valley	August 4, 5 and 6
Los Angeles	August 7, 8 and 9
Grand Canyon	August 10
Denver	August 13

Chairman Ortman of the Western Committee sends enthusiastic accounts of the plans being perfected for the comfort and enjoyment of the visiting ceramists and their families.

Members are requested to send in their names for reservations to the Office of the Secretary, Lord Hall, O. S. U., Columbus, Ohio, on or before June 1, 1924.

OFFICERS OF THE GLASS DIVISION

G. E. Barton, Chairman of Glass Division

G. E. Barton, elected chairman of the Glass Division at the Atlantic City Meeting, was born at Worthington, Mass., May 9, 1871, of old New England stock. He received the degree of B.S. from the Worcester Polytechnic Institute in 1891, and M.S. from George Washington University in 1895. He was assistant Chemist at the Naval Torpedo Station, Newport, R. I., 1891–92, Chemist to The Aetna Powder Co., Aetna, Indiana, 1892–94; and private assistant to Dr. Charles E. Munroe, the explosives expert, 1894–96.

G. E. BARTON

From 1896 to the present he has been the chief scientific advisor of Whitall Tatum Company. This concern made and marketed the first American borosilicate glass, for other than optical purposes, as "Nonsol" Chemical Ware in 1902.

He is a member of the AMERICAN CERAMIC SOCIETY, The American Chemical Society, The Society of Chemical Industry (London), The Societe de Chemie Industrielle (Paris), The American Institute of Chemical Engineers, The Society of Glass Technology (England), and a fellow in The American Association for the Advancement of Science.

In the American Chemical Society, he served on the Committee on "Graduated Chemical Glassware" which convinced that organization of the necessity of a Bureau of Standards and which was active in obtaining the passage by Congress of the Bill creating the

same. Correspondence which he had with President Hillebrand of the same Society in 1906 led to the appointment of a committee of which he was a member on the relation of industrial chemists to the Society. The work of this group led to the publication of *Chemical Abstracts* in 1907, and of The *Journal of Industrial and Engineering Chemistry* in 1909. He also has served the same organization as Associate Editor of The *Journal of Industrial and Engineering Chemistry*, Assistant Editor of *Chemical Abstracts* during its entire existence, Councillor from 1908 to the present, and Chairman of the Philadelphia Section in 1921.

ALFRED N. FINN

Alfred N. Finn, Newly Elected

Born and educated in Denver, Colo. Graduate of the University of Denver, A.B. (1906), A.M. (1909), having specialized in chemistry, mathematics and physics. Instructor in Chemistry, University of Denver, until appointment at Bureau of Standards in 1911. After eight years in chemical testing of structural materials, he resigned to enter the Research Department of the Hydraulic Steel Co., Cleveland, Ohio. Reinstated at Bureau of Standards in 1920 in his present position in the Glass Section. He is a member of the American Chemical Society, 1912, American Society for Testing Materials in 1913, AMERICAN CERAMIC SOCIETY, 1922, and the Optical Society of America, 1923.

NOTES AND NEWS

SOCIETY OF GLASS TECHNOLOGY MEETINGS

The February meeting of the Society of Glass Technology was held in Sheffield on February 20. In the morning there was an exhibition and demonstration of modern pyrometers at the Department of Glass Technology of the University. The following firms exhibited:

1. The Bowen Instrument Co., Ltd.
2. The Cambridge & Paul Instrument Co., Ltd.
3. The Foster Instrument Co.
4. The Optical Pyrometer Syndicate.
5. Messrs. Booth & Miller also demonstrated their New Temperature Controller.

At the afternoon session the subject under discussion was "The Use of Pyrometers in Glass Works." Five papers were presented.

I. "The Use of Pyrometers in Glass Works," by E. A. Coad-Pryor

The value of pyrometric equipment in a glass factory depends essentially on three factors:—

1. The reliability of the pyrometer itself, particularly the clock-work;
2. The skill which is expended on its maintenance; and
3. The attitude with which the management, foremen and furnace operators regard the pyrometer.

Of these three the last was regarded as the most important. The pyrometer in no way displaced the trained eye; its real function was to supply further information

in order that a highly skilled operator might be able to get more out of his plant than had hitherto been possible.

The range of temperatures to be measured could conveniently be subdivided into 3 groups.

1. The range 0° to 700°C, covering leers, stack temperature, producer gas, etc.
2. From 700° to 1200°C, regenerator temperature, pot work, and
3. Above 1200°C, the temperature of the melting furnaces.

In the first group the thermocouple was the most convenient instrument to use. Some sort of a portable thermocouple should be part of every works equipment. A convenient couple for low temperature work was iron-constantan: the wire to be about 22 gauge.

In the high temperature ranges an optical or total radiation pyrometer was, as a rule, the most convenient. The tank furnace might be subdivided into 3 zones: the melting zone, the plaining zone, and the refining end. Two permanent pyrometers should be used on each furnace, one on the refining and the other sighting through a hole in the end wall at the melting end of the furnace. The use of couples embedded in the wall of the tank or in the crown caused probably more trouble than they were worth.

The optical or radiation pyrometer if used with discretion, was the most reliable and the most easily applied. The author's experience was that the optical instruments gave less variable readings than did the radiation instruments. The all important factor with any installation was the training of the staff and operators to use the instruments with intelligence as an aid to the maximum efficiency in furnace manipulation. A bibliography was added to the paper.

II. Continuous High Temperature Measurements in Glass Works, by W. M. Clark

In the strictest sense of the term there was probably no absolutely accurate method existing for constantly determining glass house temperatures. We could only approach this desirable aim by refinements of installation and careful maintenance, and this meant both equipment and maintenance expense. Therefore, in considering the subject of a pyrometer installation the glass manufacturer must balance the factors of what his demands for accuracy will be worth against the initial and operating costs of various systems. It is always advisable to install both the indicating and recording type of instrument, side by side.

Experience at a number of modern well laid out plants showed that pyrometric measurements were reflected in the costs sheets. The morale of the furnace men was improved by eliminating the human errors of judgment in guessing at temperatures and cost per unit of output decreased. With improvements in pyrometric equipment the tendency was for their more extensive use around glass works. The depreciation on such equipment was not excessive, about ten per cent per annum being a fair amount, judging from successful installations and as improvements came along they could be incorporated into the system, replacing features which became obsolete and thus keeping the installation up to date. A well-planned system would reduce overall costs in a year more than sufficient to pay for the investment and often would leave several times this amount if used intelligently.

The most forceful argument for the adoption of pyrometer control in a glass works was on the score of economic savings but the information, thereby made available to the management and staff, was also important in showing each man a tangible effect of his operation on the thermal conditions. The producer man saw that good gas was necessary to maintain temperature, the furnace man saw the result of proper draft

regulation, the foreman of the finishing department could be satisfied whether the ware was being properly annealed and the whole schedule of production was benefited.

III. Recent Advances in the Design of Temperature Measuring Instruments, Etc., by R. W. Whipple

One difficulty in connection with disappearing filament pyrometers was to get two lamps which would be interchangeable. Methods for overcoming this difficulty were indicated. The speaker then said how greatly he had been impressed with what he had seen recently in the United States in the matter of automatic temperature control. He understood considerable work was being done in this connection in glass works and referred to the works of Messrs. Keuffel & Esser when leer temperatures were controlled from 200°C to 600°C. For every kind of glassware a special cooling curve was followed. In the United Kingdom automatic temperature control was being developed. The main principle in such control was a galvanometer needle which was deflected by some method. Lantern slides were then exhibited showing various forms of controller, including (1) Brown, (2) Bristol, (3) C. Engelhard, (4) Leeds & Northrup, (5) Cambridge, (6) Barr, (7) Althorpe. It should be possible to control leer temperatures by some such automatic control apparatus, and so to lessen the worries of the works manager.

IV. Practical Applications of Pyrometers to Glass Works, by C. E. Foster

Both optical and total radiation instruments were calibrated for what was known as "black body" condition and when used on hot bodies which were not technically known as "black bodies," the reading would be in error by an amount which varied with the actual condition. An ordinary large glass melting tank was by no means a "black body." The author suggested that luminous gas flames might have the power of selective emission, that is, they radiated a light which was not in proportion to their temperature, but might be of an intensity which would correspond to the brightness of a solid hot body at a much higher temperature. Considering a surface of molten glass viewed obliquely in a furnace that did not realize "black body" conditions, it obviously had a considerable reflecting power, but he found that its reflecting power as experienced in measuring with a total radiation pyrometer was relatively much less than the unoxidized surface of molten metal. Further consideration showed that this was reasonable because there was some considerable transparency in the glass so that it would actually emit a greater proportion of the heat from inside. Thus it was actually found that molten glass approached more nearly to a true "black body" than unoxidized molten metal.

V. Reflections on Pyrometer Design, by W. Bowen

Economy in fuel consumption, long life of furnaces or other heating devices employed, elimination of waste of raw materials and of irreparable losses of finished products all depend upon the raising of the heat-treated materials to no less, and no more, than the requisite temperatures. The value of pyrometers to such heat-treatment problems was now too well recognized to need discussion. A few of the standards which a good pyrometer should fulfill were as follows: (*a*) Simplicity of design and operation, (*b*) Robustness and freedom from liability to breakdown under shock or accident, (*c*) Flexibility of apparatus to meet the practical conditions, (*d*) Long and stable life of pyrometer, (*e*) Speedy response to temperature changes, (*f*) Automatic action, (*g*) Accuracy. These standards were then discussed with reference to the new "Pyro" radiation pyrometer, an instrument compact in shape, extremely portable and simple in operation.

The January Meeting.—A meeting of the Society of Glass Technology was held in the College of Technology, Manchester, on Wednesday, January 16, 1924, the Pres-

ident, W. E. S. Turner, being in the chair. A paper by the president on "Specifications for Glass" formed the basis of an interesting discussion. J. H. Steele directed attention to a circular which he had received in which the use of glass for food containers was attacked. It was further stated that glass splinters were a possible cause of appendicitis and cancer. E. A. Coad-Pryor suggested the desirability of having some open preliminary specifications based upon durability alone. What was needed was some simple test which could be easily applied in the works. Fuller specifications could be made as experience accrued. Professor Turner in the course of his reply said that his attention had already been directed to the circular to which Mr. Steele referred. As the matter was one of some importance to the glass industry he had felt constrained to consult some of the leading pathological and surgical experts in this country and to obtain their views on the subject. The answers which he had received very definitely refuted the charge that glass splinters was a cause of either appendicitis or cancer.

The next paper considered was entitled "The Production of Colorless Glass in Tank Furnaces, with Special Reference to the Use of Selenium" by A. Cousen, and W. E. S. Turner. Mr. Cousen summarized previous work done by the authors on this subject and gave the results of their latest experiments. Some types of commercial glass, including modern colorless glass jars, began to turn yellow when exposed for some time to light. This happened when stacks of jars were kept for a time in the open yards of glass factories. It was now shown that glasses which had been decolorized by selenium, together with arsenic showed this yellowing effect on exposure to sunlight. On the other hand, glasses which were originally yellow, due to the presence of selenium without arsenic, became bleached by sunlight. It had previously been observed that the yellow selenium glasses when reheated to temperatures of 500° to 600°C became distinctly deeper in color, the maximum deepening being reached at a temperature of about 550°. When, however, a number of pink glasses such as are obtained by melting batches containing selenium along with arsenious oxide or sodium nitrate are reheated at the same temperatures, distinct loss of color occurs. This loss is slow at 525° but is very appreciable even after an hour at 575°, the upper annealing temperature of the glass itself. Such a color change would be obtained in a leer when the pink glasses were being annealed, and would call for careful regulation of the temperature during the process.

A paper emanating from the Department of Glass Technology of the University of Sheffield and entitled "Further Contribution to the Study of the Effect of Alumina in Glass," was taken as read.

COLONEL PRATT IN NEW WORK

At the meeting of the State Geological Board, held in Raleigh, February 1, Colonel Joseph Hyde Pratt, who is *ex officio* Director of the State Geological and Economic Survey, tendered his resignation as State Geologist, a position he has held since 1906.

Colonel Pratt is now actively engaged in his new work as President of Western North Carolina, Inc., an inter-county association whose purpose, as its name indicates, is the advertisement and general development of the resources and material and social possibilities of the rapidly prospering mountain section of the State.

The new director is Brent S. Drane, civil engineer of Charlotte, N. Car.

The first meeting of the Czechoslovak Ceramic Society in Praha.

CZECHOSLOVAK CERAMIC SOCIETY

By Rudolf Barta[1]

New Ceramic Society, Organized in December, 1923

Czechoslovakia has long stood in need of a scientific center in ceramics. This country abounds in first class raw materials and her ceramic industry is on a high level. Therefore, on December 11 the ceramic engineers founded in Praha, the Czechoslovak Ceramic Society. It is the fifth corporation of this kind in the whole world, and the second on the Continent of Europe. The Society is organized after the American model. The membership for foreigners is Kč 50, for a Society Kč 500.

Dr. Frank Fischer,
The first president of the Czechoslovak Ceramic Society.

The *Journal* of the Society will appear occasionally. As three of the ceramic societies use the English language, our *Journal* will contain English abstracts.

Up to this time the work of our ceramists has not been known abroad, as most of our works have been written in the Czech language, which is not much known abroad.

Foreign countries have heard of us through foreign newspapers, and therefore we were supposed to belong to other nations. The interest for this new society is very great throughout Central Europe.

The first elected president is Frank Fischer, one of the most distinguished workers.

The Czechoslovak ceramists would be pleased to enter into scientific connections with the Americans.

[1] Secretary of the Czechoslovak Ceramic Society.

RESEARCH FELLOWSHIPS

At the College of Mines, University of Washington and the Northwest Experiment Station, U. S. Bureau of Mines, 1924–1925

The College of Mines of the University of Washington offers five fellowships for research in Mining, Metallurgy, and Ceramics in coöperative work with the Bureau of Mines. The fellowships are open to graduates of universities and technical schools who are properly qualified to undertake research investigations. The value of each fellowship is $810 per year of twelve months, beginning July 1st. Fellowship holders pay the usual tuition and partial laboratory fees; they register as graduate students and become candidates for the degree of Master of Science in Mining Engineering, or in Metallurgy, or in Ceramics, unless an equivalent degree has previously been earned.

The purpose of these fellowships is to undertake the solution of various problems being studied by the United States Bureau of Mines that are of especial importance to the State of Washington, the Pacific Northwest, and Alaska. The investigations consist principally of laboratory work directed largely by the Bureau's technologists. For the year 1924–1925 the following subjects have been selected for investigation:

(1) Beneficiation of coal, especially coal washing.

(2) Electrometallurgy. Iron and steel problems. Super-refractories.

(3) Ceramics. Super-refractories, whiteware bodies, and other problems.

For information write to Dean Milnor Roberts, College of Mines, University of Washington, Seattle, Washington.

BUREAU OF STANDARDS

Exhibit of Ceramic Ware

The Bureau of Standards at Washington, D. C., is sending to the various manufacturers of vitrified and semi-vitrified ware, enamelers, manufacturers of glass, art pottery concerns, and in fact to the manufacturers of every variety of ceramic ware, a form letter requesting that they submit a few samples of their product which is either intricate in shape or has some artistic value.

These samples are to be placed on permanent exhibit. Such an exhibit will be of benefit to every one concerned since it will bring before the many visitors to the Bureau the products of the American ceramic industry. The Bureau has gone to considerable trouble to prepare an adequate case for these exhibits and is making every endeavor to present them in such a way that they will appeal to the popular eye.

"Cut-Offs" for Glass Bottle Machines

For some time the Bureau has been investigating the material used for "cut-offs" which are employed to control the flow of glass in automatic bottle machines. Ten shapes were made up during the past month, using two bodies which have been found to be resistant to glass attack and spalling. It has been thought that casting instead of pressing would eliminate some of the trouble now experienced in the industry through the failure of these "cut-offs."

Judging from the raw batch of bodies sent in by manufacturers, a change in body will be necessary if casting is to replace pressing, as the present one is too deficient in plastic clay and probably contains too much impurity to cast successfully.

Compressive Strength of Sand-Lime Brick Walls

Ten sand-lime brick walls and 12 wallettes were tested in the 10,000,000 lb. vertical machine during the month. Half of these were built with cement-lime mortar and half with lime mortar. The tests showed the former to be more than twice as strong and roughly about ten times as stiff as those built with lime mortar.

The latter walls, however, showed a compressive strength of about 300 lb. per sq. in., which means that under its own weight such a wall would have to be 350 feet high before it would crush at the bottom.

Judging from the opinions of various engineers and others who have witnessed these tests, the results, covering as they do unusually large wall specimens, will furnish very valuable data for use in future construction.

BUREAU OF MINES NOTES

Refractory Kiln Survey

A number of operators of refractory kilns have asked the Department of the Interior to detail engineers of the Bureau of Mines to look over their burning conditions with the idea in view of determining whether it is likely that a saving in fuel could be effected by a service similar to that rendered to the refractories manufacturers by the Bureau last year. This work will be in coöperation with the Refractories Manufacturers Association.

Burning Problems of Industrial Kilns

Important fuel economies in the operation of industrial kilns manufacturing brick, tile and other heavy clay products have been made possible as the result of a study of the burning problems of such kilns, made by the Department of the Interior in coöperation with the Four Heavy Clay Products Associations. In the course of the investigation, engineers of the Bureau of Mines, traveling on a specially-equipped laboratory car, conducted studies of actual firing conditions at typical plants producing common brick, face brick, paving brick, and hollow building tile. The practical demonstrations of the Bureau of Mines engineers resulted generally in a considerable reduction of time of burning, a material lessening in the amount of fuel consumed, and improvement in the quality of the manufactured product. The results of this investigation have been incorporated in a report on "The Burning Problems of Industrial Kilns," published by the Four Heavy Clay Products Associations, composed jointly of The National Paving Brick Manufacturers Association, The Common Brick Manufacturers Association, The American Face Brick Association, and the Hollow Building Tile Association.

Utilization of Anhydrite

The anhydrous form of gypsum, which occurs in large quantities in some mines, is difficult to utilize. In the hope of obtaining information which may lead to a more efficient utilization of such types of gypsum, a study of the chemical and physical properties of the whole series of calcium sulphates has been undertaken by the Department of the Interior at the Non-Metallic Minerals Station of the Bureau of Mines, New Brunswick, N. J. The bureau will attempt to determine (1) the stability of gypsum and anhydrite in their relation to gypsum ore reserves and (2) the properties of anhydrite in their relation to better utilization. A preliminary study has been made of physical-chemical work that has already been accomplished, bearing on this subject. Samples of anhydrite and gypsum have been obtained from gypsum mines.

Refractories for the Melting of Platinum

Last month a sample of fused zirconium oxide was obtained from a company which is developing the production of fused zirconia on a commercial scale. Small crucibles of this fused zirconia have been made in the laboratory without an added oxide bonding material and with additions of 20% thoria or 15% aluminum. Very promising results have been obtained since several of the crucibles have satisfactorily withstood very sudden and uneven heating in the oxyacetylene flame and even quenching in water from temperatures as high as 1700° or 1800°C. Actual melting tests with platinum will be carried out in the induction furnace as soon as possible.

REQUEST FOR UNPUBLISHED DATA

The Editorial Board of International Critical Tables will appreciate receiving from scientific investigators any numerical data which they are able and willing to furnish. which have not been published prior to January 1, 1924. All data are desired which characterize the behavior of any definite material, substance or system. For the purpose of this request, such data will be divided into two classes, as follows: Class I, data which constitute the only information of the kind available; Class II, data which, in the opinion of the investigator, substantiate, extend or improve upon existing information of the same kind.

In connection with data belonging to both classes, the following information should be given: (*a*) an exact definition of the material, substance, or system to which the data apply; (*b*) the investigator's estimate of the accuracy of the values; (*c*) the name of the investigator or investigators responsible for the measurements; (*d*) the laboratory in which the investigations were carried out; (*e*) a brief statement of the experimental method used; (*f*) an exact statement of the units in which the data are expressed; and (*g*) any other supplementary information necessary for the complete characterization of the data.

For data belonging to class II, such additional data should be furnished as will enable the expert in charge of this class of data to critically evaluate the new in comparison with the older data. Manuscript or corrected page proofs should be furnished where possible.

Any data belonging to class I received prior to January 1, 1925, and any data belonging to class II received before July 1, 1924, will be in time for inclusion in "International Critical Tables," and the source of all data so included will be indicated by "Private Communication from," etc., or in such other manner as the author may prefer, unless a literature reference becomes available before going to press. Data determined by members of the staff of a research laboratory should be forwarded through the Director of the laboratory. All data should be sent to "International Critical Tables," National Research Council, Washington, D. C.

ELECTRIC FURNACE REFRACTORIES

The American Electrochemical Society will have a round table discussion of electric furnace refractories in New York City, April 24. They desire that as many as are interested shall attend. Dr. M. L. Hartman of Carborundum Co., Niagara Falls is in charge.

CALENDAR OF CONVENTIONS

Organization	Date	Place
AMERICAN CERAMIC SOCIETY (Summer Meeting)	July 21– Aug. 1924	Trip to Pacific Coast
AMERICAN CERAMIC SOCIETY (Annual Meeting)	Feb. 16–21, 1925	Columbus, Ohio
American Electrochemical Society	April 24	New York City
Am. Foundrymen's Assn.	Oct., 1924	
Am. Gas Assn., Inc.	Oct., 1924	

Organization	Date	Place
Am. Iron and Steel Institute	May 23, 1924	New York
Am. Zinc Institute, Inc.	Apr. 28–29, 1924	St. Louis, Mo.
Assn. of Scientific Apparatus Makers of U. S. A.	Apr. 25–26, 1924	Washington, D. C. Bureau of Standards
British Assn. for the Advancement of Science	Aug. 6–13, 1924	Toronto, Canada
Chamber of Commerce of the U. S. A.	May 6–8, 1924	Cleveland, Ohio
Chemical Equipment Assn.	Sept., 1924	
Eastern Clay Products Assn.	Apr., 1924	
Eastern Paving Brick Mfrs. Assn.	Dec. 9, 1924	New York (?)
Glass Container Assn. of Amer.	Apr. 25, 1924	Atlantic City
Glazed and Fancy Paper Mfrs. Assn.	Wk. of Apr. 7, 1924	New York
Manufacturing Chemists' Assn.	June, 1924	New York
Natl. Assn. of Mfrs. of U. S. A.	May 19–21, 1924	New York
Natl. Assn. of Stove Mfrs.	May 14–15, 1924	New York, Hotel Astor
Natl. Bottle Mfrs. Assn.	Last Wk. Apr., 1924	Atlantic City
Natl. Glass Distributor's Assn.	Dec., 1924	Pittsburgh
Natl. Ornamental Glass Mfrs. Assn. of U. S. and Canada	June 24–26, 1924	New York
Natl. Paving Brick Mfrs. Assn.	Dec., 1924	
Penna. Gas Assn.	April, 1924	Atlantic City
Society of Promotion Engineering Education	July, 1924	Boulder, Colo.
Stoker Mfrs. Assn.	May or June, 1924	
U. S. Potters Assn.	Dec., 1924	Washington, D. C. (?)
Western Glass and Pottery Assn.	June 15, 1924	Pittsburgh
Western Society of Engineers	June 4, 1924	Chicago

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Metal & Thermit Corp.
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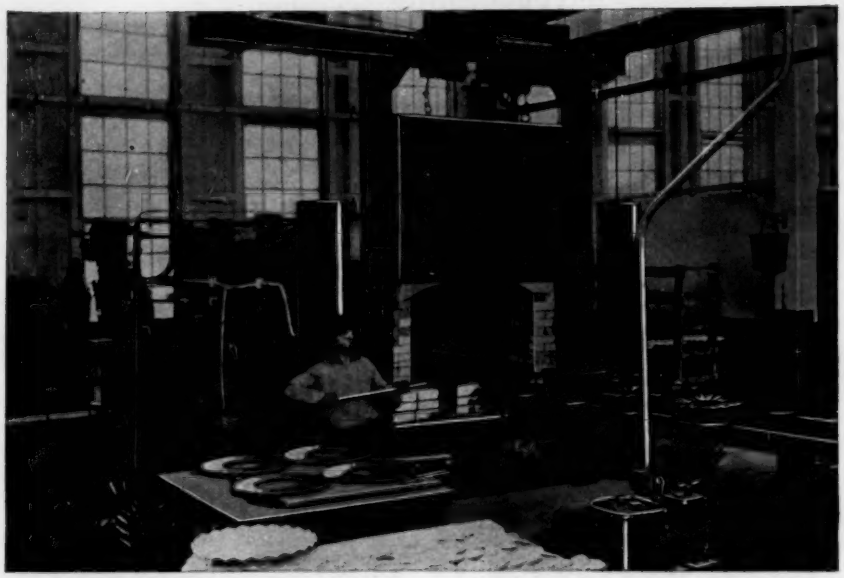

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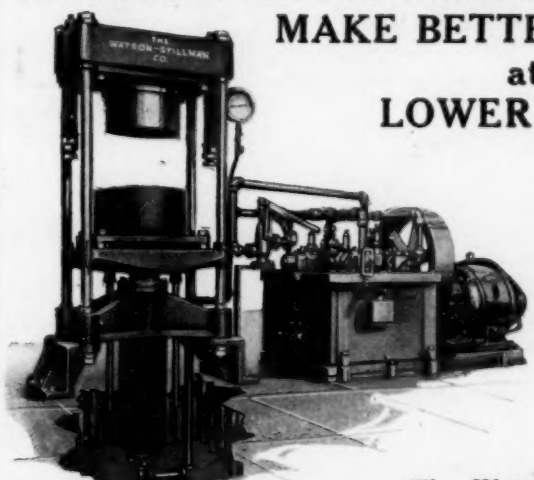

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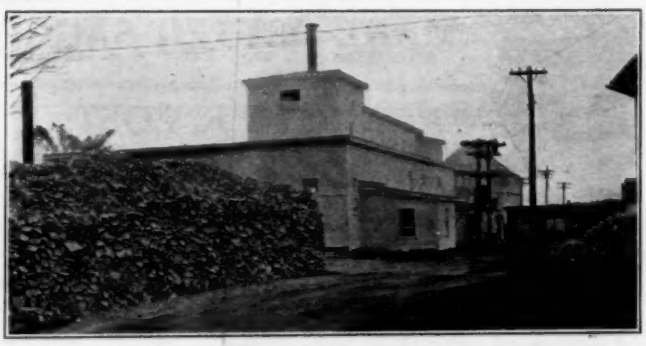

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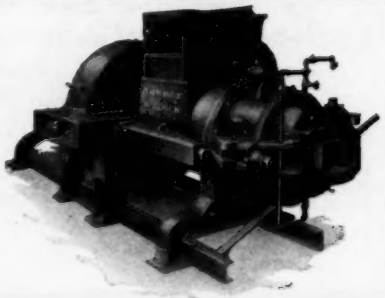

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CERAMIC BREVITIES

R. T. Vanderbilt Company take over the McNamee Clay Sales

R. T. VANDERBILT COMPANY announce that they have formed a new clay producing Company, the North American Clay Company, which has taken over their Continental Clay Company at Langley, S. C., and the McNamee Kaolin Corporation at Bath, S. C.

The production will be under the supervision of their Mining Engineers and the sales will be handled exclusively by the R. T. Vanderbilt Co.

The McNamee mine has been in operation since 1868 and is the oldest and best known of the white clay mines. The body of clay is one of the largest known deposits and has been estimated as high as 15 million tons. A large investment is being made to increase the production and improve the quality of this clay, which is used by the pottery, paper, paint and several other industries.

It is expected that the new company will have the largest production of white clay of any American Mine. The pottery grade will be sold under the brands, "Peerless," "McNamee" and "Dixie Sagger."

The Alaska Refrigerator Co. at Muskegon, Mich., after thoroughly investigating the porcelain enameling field, has awarded a contract to the Porcelain Enamel & Manufacturing Co., Baltimore, Md. for the installation of a two-furnace enameling plant, in which they will porcelain enamel their refrigerator linings. Construction of their building is now under way.

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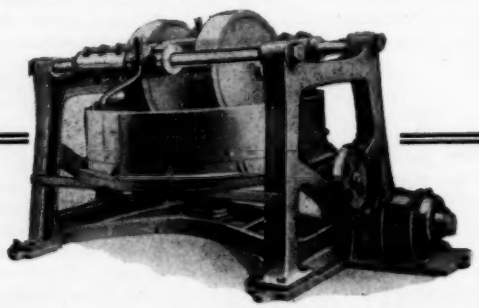

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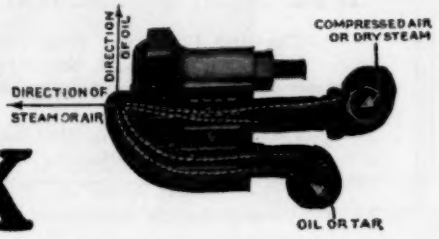

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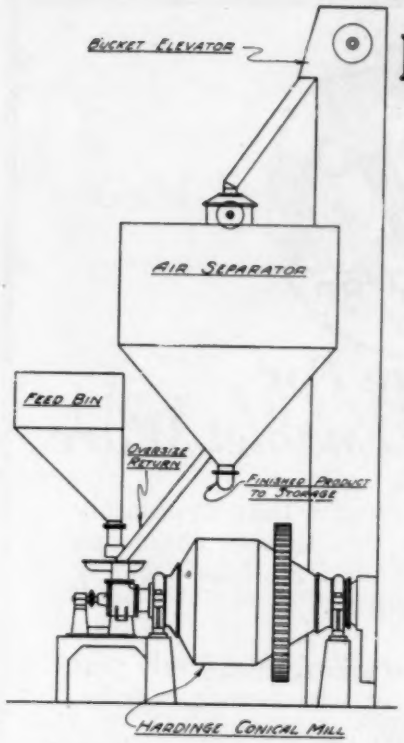

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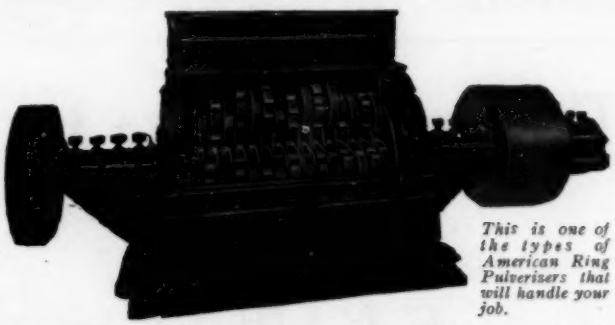

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